XEROX

Xerox University Microfilms
Ann Arbor, Michigan 48106

WESTERN AMERICANA

Reproduced from the original in the collection of
THE HENRY E. HUNTINGTON LIBRARY AND ART GALLERY

DEPARTMENT OF THE INTERIOR,
CENSUS OFFICE.

ROBERT P. PORTER,
Superintendent.
Appointed April 20, 1889; resigned July 31, 1893.

CARROLL D. WRIGHT,
Commissioner of Labor in charge.
Appointed October 5, 1893.

REPORT

ON

AGRICULTURE BY IRRIGATION

IN THE

WESTERN PART OF THE UNITED STATES

AT THE

ELEVENTH CENSUS: 1890.

F. H. NEWELL,
SPECIAL AGENT.

WASHINGTON, D. C.:
GOVERNMENT PRINTING OFFICE.
1894.

HD1739
A14U4

CONTENTS.

Page

Letter of transmittal of the Commissioner of Labor in charge to the Secretary of the Interior vii

Western part of the United States:

Number of farms and area irrigated 1, 2
Percentage of land surface irrigated 2, 3
Percentage of number of farms irrigated 3
Percentage of farm area irrigated 3, 4
Character of crops and proportion irrigated 4, 5
Value of land and crops 5, 6
Size of farms 6-8
Cost of irrigation 8, 9
Total investment and enhanced value 9-11
Cost of irrigating canals 11
Water supply 11, 12
Duty and value of water 12, 13
Rainfall 13, 14
Artesian wells 14-19
Reservoirs 19
Methods of conducting water 19, 20
Methods of applying water 20, 21

States and territories:

Arizona 22-32
California 33-89
Colorado 90-135
Idaho 136-156
Montana 157-176
Nevada 177-192
New Mexico 193-201
Oregon 202-217
Utah 218-235
Washington 236-247
Wyoming 248-256

Subhumid states:

General remarks 257-260
North Dakota 260-262
South Dakota 263-266
Nebraska 266-273
Kansas 273-277
Texas 278-283

LIST OF ILLUSTRATIONS.

Page.
View of cement lined canal near Santa Anita, Los Angeles county, California, illustrating improved method of conducting water. 19
View of orange orchard, showing method of applying water by basins on terraces 20
View of Kern river and canal on south side above Bakersfield, Kern county, California 51
View of cement distributing ditch, North Pomona, Los Angeles county, California, illustrating method of distributing water to orchards 57
View of distributing ditch, Los Angeles county, California, illustrating method of conserving water by cement lined ditches 59
View of 52-inch redwood pipe crossing Warm Springs creek near Redlands, San Bernardino county, California, on the main high line of the Bear Valley canal 72
View of artesian well and measuring device, Gage system, San Bernardino county, California 73
View at upper end of tunnel about one-half mile below head of North Poudre canal, Larimer county, Colorado 118
Scene on Rio Grande canal near Del Norte, Colorado, showing bifurcation gates, about 2 miles below main head gate 128
Scene on south branch of Payette river at point of diversion of the canal of Payette Valley Irrigation and Water Power Company, about 2 miles above Emmett, Ada county, Idaho 141
View of Bruneau dam and canal, Owyhee county, Idaho 155
View of valley and bench lands along West Gallatin river, Gallatin county, Montana 166
View in canyon of Bear river, Boxelder county, Utah, looking east, showing waste ways of Bear River canal on the left 223
View of Belmont canal near head, Cheyenne county, Nebraska 261

MAPS.

Western part of the United States, showing location of areas irrigated in 1889 2
Irrigation canals in the Gila valley, Arizona 28
Relative location of irrigation districts of California 39
Irrigating canals in the vicinity of Fresno, Fresno county, California 48
Irrigating canals in the vicinity of Bakersfield, Kern county, California 54
Irrigating canals in the vicinity of Tulare, Tulare county, California 85
Colorado, showing irrigated areas in 1889 91
Principal irrigating canals of Conejos and Rio Grande counties, Colorado 105
Irrigating canals in the vicinity of Greeley, Weld county, Colorado 134
Idaho, showing irrigated areas in 1889 137
Irrigating canals in the vicinity of Idaho Falls, Bingham county, Idaho 147
Montana, showing irrigated areas in 1889 157
New Mexico, showing irrigated areas in 1889 193
Utah, showing irrigated areas in 1889 218
Wyoming, showing irrigated areas in 1889 248
Irrigating canals along Arkansas river in western part of Kansas 275

DIAGRAMS.

Classification of irrigated farms according to size 7
Annual rainfall at important stations in the western part of the United States 13
Average monthly precipitation at important stations in the western part of the United States 14
Daily discharge of Salt river at Arizona dam, Maricopa county, Arizona 27
Daily discharge of Arkansas river at Canyon, Fremont county, Colorado 111
Daily discharge of Rio Grande above Del Norte, Rio Grande county, Colorado 128
Daily discharge of West Gallatin river below Spanish creek, Gallatin county, Montana 167
Daily discharge of Yellowstone river at Horr, Park county, Montana 174
Daily discharge of Truckee river at Vista, Washoe county, Nevada 190
Daily discharge of Owyhee river at Rigsbys, Malheur county, Oregon 214
Daily discharge of Bear river at Collinston, Boxelder county, Utah 223

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
CENSUS OFFICE,
WASHINGTON, D. C., May 31, 1894.

SIR:

I have the honor to transmit herewith the Report on Agriculture by Irrigation in the western part of the United States, prepared by Mr. Frederick Haynes Newell, special agent, under the general direction of Mr. John Hyde, formerly special agent in charge of the division of agriculture.

Very respectfully,

CARROLL D. WRIGHT,
Commissioner of Labor in charge.

Hon. HOKE SMITH,
Secretary of the Interior.

INTRODUCTION.

BY F. H. NEWELL.

This report shows the relative importance of irrigation under the general heads of the Arid region, where irrigation is essential, and the Subhumid region, where the rainfall in some seasons tempts the agriculturist to depend upon a supply that fails to develop his crops in other seasons.

In the first, or arid region, are embraced part or the whole of certain states and territories, namely: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

In the subhumid region are embraced parts of certain states, namely: North Dakota, South Dakota, Nebraska, Kansas, and Texas.

The following condensed tables present the number of persons who irrigate their farms, aggregating 52,584; the acres irrigated, aggregating 3,564,416; the average size of irrigated farms for the regions treated, 68 acres; the average value of products per acre for the arid region, $14.89, first distributed by states and territories for the arid region, and next by states for the subhumid region.

TOTAL NUMBER, TOTAL AREA, AVERAGE SIZE, AND AVERAGE VALUE OF PRODUCT PER ACRE OF IRRIGATED FARMS IN THE ARID REGION.

STATES AND TERRITORIES.	Number of irrigators in 1889.	Area irrigated in 1889, in acres.	Average size of irrigated farms, in acres, in 1889.	Average value of products per acre in 1889.
Total	52,584	3,564,416	68	$14.89
Arizona	1,075	65,821	61	13.92
California	13,732	1,004,233	73	19.00
Colorado	9,650	890,735	92	13.12
Idaho	4,323	217,005	50	12.93
Montana	3,706	350,582	95	12.96
Nevada	1,167	224,403	192	12.92
New Mexico	3,085	91,745	30	12.80
Oregon	3,150	177,944	56	13.90
Utah	9,724	263,473	27	18.03
Washington	1,046	48,799	47	17.09
Wyoming	1,917	229,676	119	8.25

The table for the subhumid region does not show the value of products per acre.

TOTAL NUMBER, TOTAL AREA, AND AVERAGE SIZE OF IRRIGATED FARMS IN THE SUBHUMID REGION.

STATES.	Number of irrigators in 1889.	Area irrigated in 1889, in acres.	Average size of irrigated farms, in acres, in 1889.
Total	1,552	66,965	43
North Dakota	7	445	64
South Dakota	189	15,717	83
Nebraska	214	11,744	55
Kansas	519	20,818	40
Texas	623	18,241	29

The area irrigated by artesian wells was but 1.429 per cent of the irrigated land. The number of wells, the area they irrigated in each state and territory, with various details, appear in the following table:

ARTÉSIAN WELLS ON FARMS IN JUNE, 1890.

STATES AND TERRITORIES.	Total number.	Average depth in feet.	Average cost per well.	Average discharge in gallons per minute.	WELLS USED IN IRRIGATION.		Acres irrigated per well.	Total acreage irrigated.
					Per cent.	Computed number.		
Total	8,097	210.41	$245.58	54.43	48.54	3,930	13.21	51,896
California	3,210	243.00	425.00	164.00	64.17	2,060	18.63	38,378
Colorado	596	251.00	221.00	39.00	57.85	345	18.01	6,213
Idaho	28	83.00	53.00	11.00	50.00	14	13.21	185
Kansas	50	202.00	175.00	44.00	41.37	24	13.71	329
Montana	14	366.00	473.00	28.00	42.85	6	3.00	18
Nebraska	91	247.00	173.00	13.00	7.40	7	1.00	7
Nevada	33	215.00	607.00	6.00	60.00	20	1.00	20
North Dakota	461	196.00	265.00	21.00	2.17	10	2.00	20
Oregon	6	70.00	250.00	15.00	50.00	3	4.00	12
South Dakota	527	216.00	158.00	51.00	13.46	71	6.68	474
Texas	534	292.00	359.00	19.00	27.32	146	3.00	438
Utah	2,524	146.00	78.00	26.00	48.49	1,224	4.74	5,802
Washington	9	127.00	312.00	89.00	....	....	....	....
Wyoming	5	210.00	456.00	8.00	....	....	....	....

IRRIGATION IN THE WESTERN PART OF THE UNITED STATES.

NUMBER OF FARMS AND AREA IRRIGATED.

The area irrigated within the arid and subhumid regions in the western part of the United States during the census year ending May 31, 1890, aggregated 3,631,381 acres, or 5,674.03 square miles, approximately four-tenths of 1 per cent of the total land area west of the one hundredth meridian. Of this irrigated area very nearly two-thirds was devoted to the raising of various kinds of forage. The total number of irrigators was 54,136, or, more correctly, this was the aggregate number of farms or agricultural holdings upon which crops were raised by means of irrigation. In this connection it may be well to note that the definition of a farm adopted for the purposes of the census includes "all considerable nurseries, orchards, and market gardens, owned by separate parties, which are cultivated for pecuniary profit and employ as much as the labor of one able-bodied workman during the year". "A farm is what is owned or leased by one man and cultivated under his care. A distant wood lot or sheep pasture, even if in another subdivision or district, is to be treated as a part of the farm, but wherever there is a resident overseer or a manager there a separate farm is to be reported". Under this classification a person can have but one farm, unless the estate is so large as to require a resident farmer upon each tract.

The following table gives the items mentioned above for each state and territory lying within the arid region, and also for the states largely within the subhumid region on the east, the statistics for these latter being grouped under the single designation "subhumid region":

NUMBER OF IRRIGATORS, AREA IRRIGATED, AVERAGE SIZE OF IRRIGATED FARMS, AND AVERAGE VALUE OF PRODUCTS PER ACRE IN EACH STATE AND TERRITORY IN 1889.

STATES AND TERRITORIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.	Average value of products per acre.
Total	54,136	3,631,381	67	$14.89
Arizona	1,075	65,821	61	13.92
California	13,732	1,004,233	73	19.00
Colorado	9,659	890,735	92	13.12
Idaho	4,323	217,005	50	12.93
Montana	3,706	350,582	95	12.96
Nevada	1,167	224,403	192	12.92
New Mexico	3,085	91,745	30	12.80
Oregon	3,150	177,944	56	13.90
Utah	9,724	263,473	27	18.03
Washington	1,046	48,799	47	17.09
Wyoming	1,917	229,676	120	8.25
Subhumid region	1,552	66,965	43	....

The average size of such portions of farms as were actually irrigated was 67 acres. This is the result obtained by dividing the total area irrigated by the total number of holdings. This acreage was large, from the fact that in many of the states of the far west large areas of hay lands were flooded, little care or attention being bestowed upon them. This was notably the case in Nevada and Wyoming, and to a less extent in Montana and Colorado.

The average value of products per acre from this irrigated land was $14.89, this being the quotient obtained by dividing the total value of all products "sold, consumed, or on hand in 1889" by the number of acres irrigated. There was a tendency apparent from many of the returns received from farmers to underestimate the value of products and to overestimate the acres irrigated. As a result the value of products per acre obtained in this way was far less than has been popularly supposed was obtained from irrigated lands.

The term "subhumid" is generally understood as applying to a portion of the Great Plains lying to the east of the arid region, and is so used in this report upon irrigation. As a matter of course there is on the western side of the arid region a strip of country which may be designated as subhumid, but this area, on account of the diversified topography, is comparatively narrow and restricted, since the arid region extends on the southwest to the shores of the Pacific ocean and on the northwest to the Cascade range. For purposes of discussion the subhumid region is therefore considered as extending in a broad belt lying across the country in a north and south position and including portions of the states of North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas. The western extremity of Texas lies far within the arid region, but since the greater part of Texas is subhumid, the irrigation statistics for the whole state have been placed in this category.

The following table gives for these subhumid states the principal facts relating to irrigation, namely, the number of irrigators or holdings, the acreage irrigated, and the average number of acres in each holding. The average value of products has not been ascertained, since in these states, where some crops were raised by irrigation and others without the artificial application of water, it has been impossible to discriminate between the products raised by these two methods of agriculture. The table shows in a general way an increase in the number of irrigators and in acreage irrigated from north toward the south, which is due largely to the fact that conditions of summer aridity increase with lower latitudes, and also to the greater density of population and more easily available water supply toward the south.

NUMBER OF IRRIGATORS, AREA IRRIGATED, AND AVERAGE SIZE OF IRRIGATED FARMS IN THE SUBHUMID STATES IN 1889.

STATES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.
Total	1,552	66,965	43
North Dakota	7	445	64
South Dakota	189	15,717	83
Nebraska	214	11,744	55
Kansas	519	20,818	40
Texas	623	18,241	29

The relative position of these irrigated areas in both arid and subhumid regions is shown on the accompanying plate, the small green patches, mainly along the streams, indicating the principal places where crops were raised by the artificial application of water. In size these patches of color are not comparable among themselves, as on the scale of the map it is impossible to represent them in their true proportion, and where a number of small holdings or groups of holdings are near together they have been run into one spot whose size is relatively too large.

PERCENTAGE OF LAND SURFACE IRRIGATED.

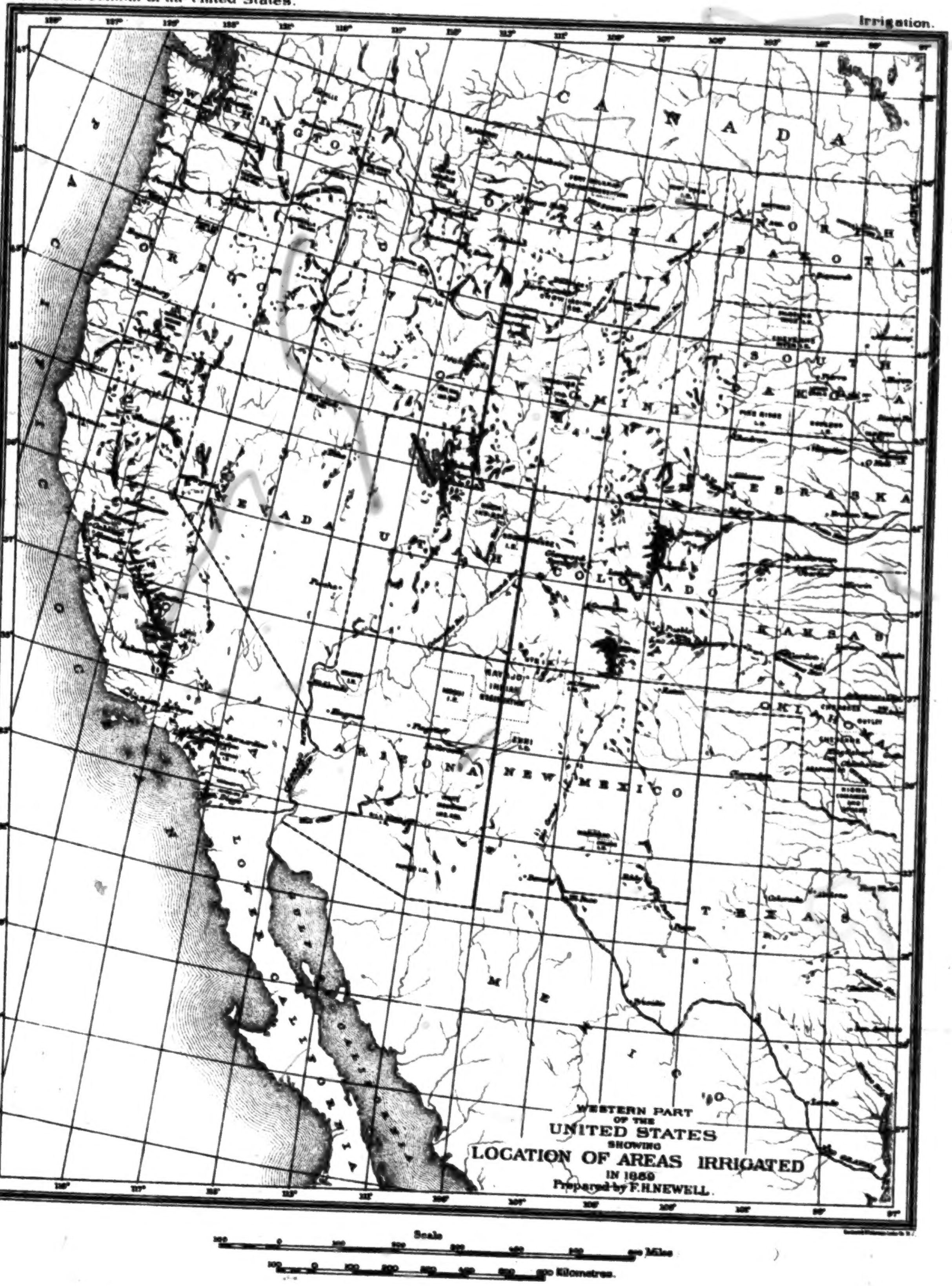
The relative number of agricultural holdings on which irrigation was practiced and the proportion of these as regards area are shown in the appended table. Omitting the subhumid states, in which irrigation may be considered as exceptional, the total area irrigated was 3,564,416 acres, or 5,569.40 square miles. This is almost exactly one-half of 1 per cent of the total land area of the states and territories within which irrigation was commonly practiced. In this comparison the area of 13 eastern counties of Washington and 16 eastern counties of Oregon has been taken instead of the total for the two states. The largest percentage by states was found in Colorado, reaching 1.34 per cent, and the smallest percentage irrigated among arid states and territories was in Arizona, where the area was less than one-tenth of 1 per cent.

AREA IRRIGATED IN STATES AND TERRITORIES WHOLLY OR PARTIALLY WITHIN THE ARID REGION.

STATES AND TERRITORIES.	AREA IRRIGATED.		Total number of farms enumerated.	HOLDINGS CONTAINING IRRIGATED AREAS.			
	Acres.	Per cent of entire land surface of state.		Total number.	Per cent of number of farms in state.	Total area in acres.	Per cent of total area irrigated.
Total	3,564,416	0.50	123,143	52,584	42.70	17,199,925	20.72
Arizona	65,821	0.09	1,426	1,075	75.39	152,345	43.21
California	1,004,233	1.01	52,894	13,732	25.96	5,622,000	17.86
Colorado	890,735	1.34	16,389	9,659	58.94	2,865,000	31.09
Idaho	217,005	0.40	6,603	4,323	65.47	832,000	26.08
Montana	350,582	0.38	5,603	3,706	66.14	1,520,853	23.05
Nevada	224,403	0.32	1,277	1,167	91.39	1,587,700	14.13
New Mexico	91,745	0.12	4,458	3,085	69.20	510,177	17.98
Oregon (a)	177,944	0.39	10,159	3,150	31.01	1,120,000	15.89
Utah	263,473	0.50	10,517	9,724	92.46	1,196,000	22.03
Washington (b)	48,799	0.23	10,692	1,046	9.78	287,000	17.00
Wyoming	229,676	0.37	3,125	1,917	61.34	1,506,850	15.24

a Sixteen eastern counties only.

b Thirteen eastern counties only.



WESTERN PART
OF THE
UNITED STATES
SHOWING
LOCATION OF AREAS IRRIGATED
IN 1889
Prepared by F. H. NEWELL.

CANADA
WASHINGTON
MONTANA
NORTH DAKOTA
OREGON
IDAHO
SOUTH DAKOTA
WYOMING
NEBRASKA
NEVADA
UTAH
COLORADO
KANSAS
CALIFORNIA
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
MEXICO
LOWER CALIFORNIA
GULF OF CALIFORNIA
PACIFIC OCEAN
NAVAJO INDIAN RESERVATION
Scale
Miles
Kilometres

Considering the counties of these states in the order of the percentage of total area irrigated, Boulder county, Colo., leads the list with 14.04 per cent of its entire area cultivated by means of irrigation in 1889. Next comes the county south of this, namely, Jefferson, with 7.42 per cent. Both of these are in the vicinity of Denver and at the eastern front of the Rocky mountains, where the water supply is unusually large and convenient. The following 10 counties contain the largest proportions of lands upon which crops were raised by irrigation in 1889:

	PER CENT.		PER CENT.
Boulder county, Colo	14.04	Salt Lake county, Utah	5.06
Jefferson county, Colo	7.42	Tulare county, Cal	4.71
Davis county, Utah	6.93	Custer county, Colo	4.56
Orange county, Cal	6.72	Cache county, Utah	4.43
Weber county, Utah	5.13	Weld county, Colo	4.30

PERCENTAGE OF NUMBER OF FARMS IRRIGATED.

The total number of farms enumerated in the 11 western states and territories named in the preceding table was 123,143, omitting certain western counties of Oregon and Washington. In comparison therewith it has been found that 52,584, or 42.70 per cent, of these farms contained irrigated areas; that is to say, within the arid region, or at least within the area bounded by state and county lines, and including the greater part of the arid region, irrigation was practiced upon less than one-half of the holdings, which under the census classification were designated as "farms". Of the remaining farms, on which irrigation was not practiced, by far the greater number were what are commonly known as cattle ranches, while on others crops were raised by dependence upon the rainfall.

The largest proportion of irrigated farms to the total number was found in Utah, where over nine-tenths of the agricultural holdings contained irrigated areas. The smallest proportion was in Washington, the 13 eastern counties of which, although regarded as being in part, if not wholly, within the arid region, contained relatively a small number of irrigated areas, aggregating in fact less than one-tenth of the total number of farms. Arranging the states and territories in the order of the importance of irrigation as shown by this classification, the results obtained are:

STATES AND TERRITORIES IN THE ORDER OF THE PROPORTION OF THE NUMBER OF FARMS IRRIGATED TO THE TOTAL NUMBER OF AGRICULTURAL HOLDINGS.

	PER CENT.		PER CENT.
1. Utah	92.46	7. Wyoming	61.34
2. Nevada	91.39	8. Colorado	58.94
3. Arizona	75.39	9. Oregon (*a*)	31.01
4. New Mexico	69.90	10. California (*b*)	25.96
5. Montana	66.14	11. Washington (*c*)	9.79
6. Idaho	65.47		

a Sixteen eastern counties only.
b Including the whole state. (See following paragraph.)
c Thirteen eastern counties only.

Considering this table as a whole, it may be said that in the states and territories in the upper part of the list irrigation was the rule, while in those toward the foot it had less importance, and in the case of Washington it may be considered as almost exceptional. The relative position of California requires explanation, for in that state, with its enormous area and great diversity of topography, irrigation plays a peculiar part. In the northern and southern counties irrigation was practiced on a great majority of the farms, while in the counties near the center of the state, especially those bordering upon the bay of San Francisco or the Pacific ocean, it has been exceptional, there being but few counties in the state where it is not practiced to a greater or less extent. If the bay and coast counties, 14 in number, are deducted, California takes a position above Oregon, thus standing ninth in the list instead of tenth, with a percentage of 48.65 of the farms irrigated.

PERCENTAGE OF FARM AREA IRRIGATED.

The total area of the 52,584 agricultural holdings of which a part was irrigated, as shown by the preceding table, was 17,199,925 acres, or an average of 327.09 acres each. The total area irrigated was 3,564,416 acres, or 20.72 per cent of the total area of these farms. In other words, in these 11 states and territories less than half of the farms contained irrigated areas, and of this latter number one-fifth of the area was successfully irrigated. If now it is assumed that the average size of the agricultural holdings, 327.09 acres, derived as above from less than half of the farms, applies to the whole, 123,143 farms, the total acreage of these agricultural holdings would be 40,278,844 acres.

In comparison with this total farm area of 40,278,844 acres the 3,564,416 acres of irrigated crop formed evidently only 8.85 per cent of the land owned by farmers within the states and territories designated. This is a significant fact, especially in comparison with the water supply, for it has been found upon a detailed examination of each county and locality that as a rule the greater part if not all of the easily available water supply has been utilized, and in 1888 and 1889 the losses through drought were enormous, yet less than one-tenth of the land belonging to the farmers actually produced a crop by means of irrigation. It must be borne in mind, however, that a portion of the remaining nine-tenths, especially in the state of California, does not require irrigation, and that a still greater portion is unquestionably above the reach of water; but from a careful consideration of these figures it would seem as though all of the water supply of the arid region must be needed to properly irrigate the lands already owned by farmers and not fully utilized, provided that these lands are so situated as to be susceptible of irrigation.

Comparing the states and territories among themselves as regards the completeness of irrigation of the area of the farms which were wholly or in-part cultivated in this manner, it is seen that Arizona stood at the head, with a percentage of 43.21, while Nevada came last, with only 14.13 per cent of the area of each farm irrigated. Arranging these in the order of this relation, the following result is obtained:

STATES AND TERRITORIES IN THE ORDER OF THE PROPORTION OF LAND IRRIGATED TO THE TOTAL AREA OF LAND IN FARMS WHOLLY OR PARTLY IRRIGATED.

	PER CENT.		PER CENT.
1. Arizona	43.21	7. California	17.86
2. Colorado	31.09	8. Washington	17.00
3. Idaho	26.08	9. Oregon	15.89
4. Montana	23.05	10. Wyoming	15.24
5. Utah	22.03	11. Nevada	14.13
6. New Mexico	17.98		

In Wyoming and Nevada the agricultural holdings were generally very large, being used chiefly for stock raising, and, therefore, as might be expected, the irrigated portions from which crops were cut were but a small percentage of the whole area. Thus, although irrigation was essential, these divisions came near the bottom of the list.

In the case of the subhumid states any comparison of the area of crop irrigated with the total area of the state would have little value, as irrigation is exceptional and is practiced in widely scattered localities. The following table shows the relation between the irrigated area and the total size of the agricultural holdings on which this method of agriculture was practiced. Taking the 5 subhumid states as a whole, only 6.40 per cent of the farms owned by men who practiced irrigation was actually cultivated in this manner. In comparing the percentages for the states, it is to be seen that these diminish in order from north to south, ranging from 34.77 in North Dakota, the highest, to 2.43 in Texas, the lowest. The small percentage in the latter state was due partly to the fact that irrigation was largely carried on by means of water from springs or wells, small areas of garden, fruit and shade trees, and forage crops being watered on each farm, even where field crops were raised by dependence upon rainfall.

TOTAL AREA OF FARMS IN SUBHUMID STATES ON WHICH IRRIGATION WAS PRACTICED, TOGETHER WITH AREA AND PERCENTAGE IRRIGATED IN 1889.

STATES.	Total area in acres.	Area irrigated in acres.	Per cent irrigated.
Total	1,045,993	66,965	6.40
North Dakota	1,280	445	34.77
South Dakota	52,466	15,717	29.96
Nebraska	81,305	11,744	14.44
Kansas	161,020	20,818	12.93
Texas	749,922	18,241	2.43

CHARACTER OF CROPS AND PROPORTION IRRIGATED.

The character of the crops raised by irrigation is shown in a broad way by the table on the following page, in which a classification has been made into two great groups, comprising the cereals on the one hand and the forage and miscellaneous crops on the other, forage forming by far the greater part of this latter group. This table serves to show that over one-third of the area irrigated was devoted to cereals, namely, wheat, oats, Indian corn, barley, rye, and buckwheat, the importance of these products being in the order named. Of the remainder of the crop over 60 per cent consisted of forage, including various native and cultivated grasses, alfalfa or lucern, and other clovers, also wheat, oats, and related cereals cut before maturity for forage purposes. The widespread practice of using the cereals for hay, especially when owing to scarcity of water a fair crop of grain could not be produced, has introduced considerable confusion in the returns, and in some instances caused the products per acre and their values to appear remarkably small. The irrigated areas devoted to fruits are included with miscellaneous crops, since, although of great value, they form but a relatively small percentage.

GENERAL CHARACTER OF CROPS IN THE ARID REGION IRRIGATED IN 1889, BY STATES AND TERRITORIES.

STATES AND TERRITORIES.	Total acreage irrigated.	FORAGE AND MISCELLANEOUS CROPS.		CEREALS.	
		Per cent.	Acres.	Per cent.	Acres.
Total	3,564,416	65.31	2,328,016	34.69	1,236,400
Arizona	65,821	65.82	43,321	34.18	22,500
California	1,004,233	47.22	474,233	52.78	530,000
Colorado	890,735	70.25	625,735	29.75	265,000
Idaho	217,005	70.97	154,005	29.03	63,000
Montana	350,582	78.61	275,582	21.39	75,000
Nevada	224,403	93.32	209,403	6.68	15,000
New Mexico	91,745	36.78	33,745	63.22	58,000
Oregon	177,944	69.99	124,544	30.01	53,400
Utah	263,473	56.35	148,473	43.65	115,000
Washington	48,799	57.99	28,299	42.01	20,500
Wyoming	229,676	91.73	210,676	8.27	19,000

Throughout the arid region as a whole over 80 per cent of the crop area, including as a matter of course the forage plants, was irrigated, but at the same time there were counties lying well within this great region where as high as from 20 to 40 per cent of the area cultivated was utilized without the artificial application of water. Examples of this were found in northern Utah, where, as in the Cache and Malade valleys, large areas were profitably cultivated by what is known as "dry farming". The large size of the counties and the restricted areas in which agriculture has been conducted render figures somewhat misleading in detail, as, for example, in the southeastern corner of California, in San Diego, San Bernardino, and adjoining counties, in which the statistics obtained apply only to the regions near the coast, where from 20 to 60 per cent of the crop areas were irrigated. The greater portion of these counties, that lying east of the mountains near the coast, can produce nothing without water artificially applied. On both sides of the main body of arid lands, as might be inferred, there were counties in which the greater part of the crop area was not under irrigation, and beyond or adjacent to these the areas in which this method of agriculture was not in use. Along the border and even well within the arid region there were localities where it was impossible to draw the line sharply between areas irrigated and those not watered, especially where on one farm part of a given crop was irrigated and the other part not. Many farmers have learned that thorough cultivation will often compensate for scantiness of precipitation, and when, as was the case in 1889, droughts were general and water was difficult to obtain, portions of the fields were dry farmed.

VALUE OF LAND AND CROPS.

The average value of the land upon which crops were raised by irrigation, and the average value of the products per acre are shown in the table on the following page, these averages being obtained by dividing total values by the number of acres for which values were given; that is to say, in cases where the returns of farm values of products were deficient, the acreage was omitted in order to obtain the averages, it being assumed that these few cases did not differ materially from the mean of all others. For the 11 states and territories given the average value of the irrigated land, including improvements, such as fences and buildings, was $83.28 per acre, ranging from $31.40 per acre in Wyoming up to $150 per acre in California. The total value of this irrigated land and its improvements thus obtained was $296,850,000.

The average value of products for the 11 states, $14.89 per acre (to nearest figure), multiplied into the number of acres, gives in round numbers a total of $53,057,000. This average value has been obtained, as above stated, by taking all the cases in which definite returns were made and assuming that they represent the general condition. In the case of the states and territories where crops are raised on the same farm both with and without irrigation it is exceedingly difficult and not unfrequently impossible to discriminate between them.

VALUE OF IRRIGATED LANDS IN ARID REGION IN 1890 AND OF THEIR PRODUCTS IN 1889.

STATES AND TERRITORIES.	Area irrigated in 1889 in acres.	VALUE OF FARMS ON JUNE 1, 1890.		VALUE OF PRODUCTS IN 1889.	
		Average value per acre.	Total value, estimated.	Average value per acre.	Total value, estimated.
Total	3,564,416	$83.28	$296,850,000	$14.89	$53,057,000
Arizona	65,821	48.68	3,204,000	13.92	916,000
California	1,004,233	150.00	150,635,000	19.00	19,080,000
Colorado	890,735	67.02	59,696,000	13.12	11,686,000
Idaho	217,005	46.50	10,091,000	12.98	2,806,000
Montana	350,582	49.50	17,354,000	12.96	4,544,000
Nevada	224,403	41.00	9,200,000	12.92	a2,899,000
New Mexico	91,745	50.98	4,677,000	12.80	1,174,000
Oregon	177,944	57.00	10,143,000	13.90	2,473,000
Utah	263,473	84.25	22,198,000	18.03	4,750,000
Washington	48,799	50.00	2,440,000	17.09	834,000
Wyoming	229,676	31.40	7,212,000	8.25	1,895,000

a The actual value of farm products for the state of Nevada as returned on the agricultural schedules was $2,705,660. The excess of the estimate in the above table is probably accounted for by the omission of valuations from many irrigated farms in which the only crop was alfalfa and other forage eaten by cattle, and which were not reported to the enumerators.

SIZE OF FARMS.

In a comparison of the relative size of irrigated holdings in various localities the fact brought out most prominently by a study of the census returns is the large size of the areas devoted mainly to the raising of forage crops, as, for example, in Nevada, Montana, and Wyoming. On the other hand, in those localities where irrigation was highly advanced, and the products were of more than usual value, the irrigated holdings were small. The condition of the water supply, and the density of settlement entered often to modify this generalization, the irrigated areas being large where water was abundant and the population was scattered.

In order to examine into the average size of the majority of irrigated areas, and to eliminate the results produced by the existence of large tracts of land owned by a few men, the table showing "relative number and size of irrigated farms" has been prepared, in which the irrigated holdings have been classified according to size. The larger areas have been placed by themselves, thus allowing the far greater number of moderate sized holdings to be considered independently. For this classification 160 acres, or a quarter section, has been taken as the basis, and for simplicity, all irrigated holdings or parts of holdings under 160 acres in area have been called throughout this report "small farms", and those of 160 acres or over have been designated as "large farms", it being understood that these terms apply only to the areas irrigated and not to the total holding of each individual, so that if a farmer owned 640 acres and irrigated 40 acres, the latter number was the one considered and it was classed as a small farm.

Out of the 54,136 holdings upon which crops were raised by irrigation in the census year there were 4,595 in which the area irrigated was 160 acres or upward, the total of the same being 1,802,605 acres, or 49.64 per cent of the whole amount irrigated; that is to say, 4,595 persons, or 8.49 per cent of those irrigating, owned very nearly one-half of the total area irrigated. The great majority of irrigators, 91.51 per cent, irrigated 1,828,776 acres, or an average of nearly 37 acres each, against an average of 392 acres upon which crops were raised by irrigation by the few large owners.

RELATIVE NUMBER AND SIZE OF IRRIGATED FARMS.

STATES AND TERRITORIES.	UNDER 160 ACRES.				160 ACRES AND UPWARD.			
	Number.	Total irrigated area in acres.	Average size in acres.	Per cent of total area.	Number.	Total irrigated area in acres.	Average size in acres.	Per cent of total area.
Total	49,541	1,828,776	37	50.36	4,595	1,802,605	392	49.64
Arizona	996	43,165	43	65.58	79	22,656	287	34.42
California	12,595	382,850	30	38.12	1,137	621,383	547	61.88
Colorado	8,227	451,215	55	50.66	1,432	439,520	307	49.34
Idaho	4,110	159,528	39	73.51	213	57,477	270	26.49
Montana	3,130	174,009	56	49.63	576	176,573	307	50.37
Nevada	823	47,812	58	21.31	344	176,591	513	78.69
New Mexico	3,022	72,069	24	78.55	63	19,676	312	21.45
Oregon	2,896	101,788	35	57.20	254	76,156	300	42.80
Utah	9,641	237,616	25	90.19	83	25,857	312	9.81
Washington	994	31,943	32	65.46	52	16,856	324	34.54
Wyoming	1,614	79,962	50	34.82	303	149,714	494	65.18
Subhumid region	1,493	46,819	31	69.92	59	20,146	341	30.08

All the cases in which 160 acres or upward of crop (large farms) were irrigated, have been tabulated (see table following) under three headings, namely, those of from 160 to 320 acres, those of from 320 to 640 acres, and those of 640 acres and upward, these figures, as before stated, applying not to the total acreage of the agricultural holding, but only to that portion upon which crops were raised by the artificial application of water.

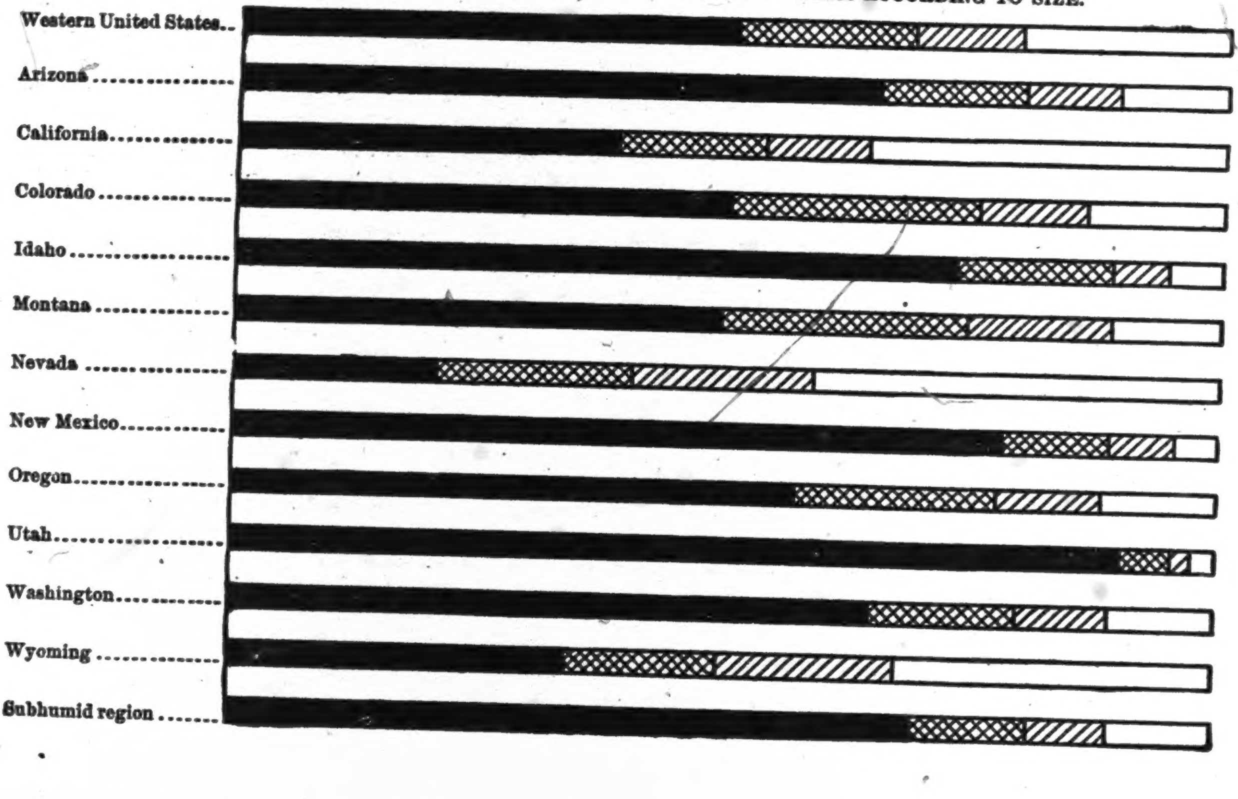
Taking the irrigated areas of 640 acres and upward, the following table shows that they numbered 411, with an aggregate area of 724,147 acres, or an average of 1,762 acres each. The 411 individuals or corporations owning these irrigated lands constituted three-fourths of 1 per cent (0.76) of the number of irrigators and held 19.94 per cent of the total area.

RELATIVE NUMBER AND SIZE OF LARGE IRRIGATED FARMS (160 ACRES AND UPWARD).

STATES AND TERRITORIES.	160 TO 320 ACRES.			320 TO 640 ACRES.			640 ACRES AND OVER.		
	Number.	Total irrigated area in acres.	Average size in acres.	Number.	Total irrigated area in acres.	Average size in acres.	Number.	Total irrigated area in acres.	Average size in acres.
Total	3,242	671,151	207	942	407,307	432	411	724,147	1,762
Arizona	57	10,454	183	15	6,515	434	7	5,687	812
California	738	152,542	207	243	103,48[illegible]	426	156	365,353	2,342
Colorado	1,113	224,518	202	244	103,845	426	75	111,157	1,482
Idaho	172	34,751	202	34	14,036	413	7	8,690	1,241
Montana	421	88,994	211	123	51,986	423	32	35,593	1,112
Nevada	201	46,556	232	91	41,494	456	52	88,541	1,703
New Mexico	46	10,202	222	14	6,460	461	3	3,014	1,005
Oregon	192	38,736	202	49	21,110	431	13	16,310	1,255
Utah	65	13,234	204	13	5,555	427	5	7,068	1,414
Washington	36	7,599	211	11	4,615	420	5	4,642	928
Wyoming	161	35,370	220	93	42,780	460	49	71,564	1,460
Subhumid region	40	8,195	205	12	5,423	452	7	6,528	933

The facts given in the two preceding tables are exhibited graphically in the following figure, which gives the percentage of total area of farms of each class to the area of all farms irrigated. The black portion of each line indicates the percentage which the total area of irrigated farms of under 160 acres each bears to all the land irrigated. For example, in Utah, New Mexico, and Idaho the small irrigated farms predominated, their aggregate being in excess of that of the larger farms. On the contrary, in Nevada, Wyoming, and California the large irrigated farms, though being as a matter of course less in number, surpassed in aggregate area those under 160

DIAGRAM ILLUSTRATING CLASSIFICATION OF IRRIGATED FARMS ACCORDING TO SIZE.



acres in size. The doubly crosshatched portion of each line or bar shows the percentage of area of farms of from 160 to 320 acres each, and the single crosshatching the percentage of those of from 320 to 640 acres each, while the open portion gives the proportion of those of 640 acres or upward. In Nevada, for example, the 52 large irrigated farms surpassed in area those of any other of the classes above enumerated, being considerably over a third of the total irrigated area.

COST OF IRRIGATION.

The statistics concerning acreages and value of land and products were taken from the enumerators' returns for each agricultural holding. Other facts now to be discussed have been obtained by direct correspondence with farmers by means of special schedules addressed to each irrigator. These schedules contained questions intended to cover facts concerning the location of irrigated land, the character of the water supply, the cost of irrigation, methods of using the water, necessity of irrigation, the use of artesian wells and pumps, also the location of canals or irrigating ditches, size and cost, and methods of distributing the water. In all about 30,000 replies have been received, and from these, after proper tabulation, certain averages have been drawn, the principal of which are shown in the following table:

AVERAGE COST OF IRRIGATION AND CULTIVATION.

STATES AND TERRITORIES.	Average first cost of water rights per acre.	Average value of water rights per acre in 1890.	Average annual cost of water per acre.	Average first cost per acre of preparation for cultivation.
Total	$8.15	$26.00	$1.07	$12.12
Arizona	7.07	12.58	1.55	8.60
California	12.95	39.28	1.60	17.48
Colorado	7.15	28.46	0.79	9.72
Idaho	4.74	13.18	0.80	9.31
Montana	4.63	15.04	0.95	8.29
Nevada	7.58	24.60	0.84	10.57
New Mexico	5.58	18.30	1.54	11.71
Oregon	4.64	15.48	0.94	12.59
Utah	10.55	26.84	0.91	14.85
Washington	4.03	13.15	0.75	10.27
Wyoming	3.62	8.69	0.44	8.23
Subhumid region	4.07	14.81	1.21	4.62

As shown above, the average first cost of bringing water to the land throughout the entire arid and subhumid regions has been $8.15 per acre. This average was derived from the statements of all persons who have constructed ditches, or have purchased water rights from others. It included all cases from those, on the one hand, where the farmers dug or plowed small ditches leading from the river or creek to their land, to those, on the other, where the irrigator purchased the right to take water from some large canal, and embraced all the intermediate conditions where water was obtained through co-operation of neighboring landowners or through partnerships of farmers. The fact that a person has used water upon a certain number of acres entitles him in many localities to certain rights or privileges. It has become customary to term property of this kind a "water right", and the first cost of applying the water to the land can be considered as the cost of this "water right".

In the different states and territories there was a wide range in this average first cost of applying water to the land, or of the water right. The highest average was in California, where the most thorough and expensive systems for saving and distributing water have been constructed. The lowest was in Wyoming, where enormous areas have been covered with water by means of ditches quickly and cheaply constructed by means of plow and scraper, the average cost in this latter state having been a little over one-fourth of that given for California.

The average value per acre of these water rights, wherever they could be considered independent of the value of the land, was $26. This was the average of the values given to this privilege or property by the owners of water rights or of independent ditches. In many localities, however, owing to the scarcity of water or to other causes, the water right can not be taken from the land without depriving the latter of its entire value, for without a water supply the land is worthless. In such cases the entire value inheres in the water right, and if it is assumed that the average value of the land was $83.28 per acre, at least $80 of this, and possibly more, must be attributed to the water right. Taking those cases in which water rights were transferable and were sold or treated like other pieces of property, the apparent enhancement to the creator of these rights has been the difference between $26 and $8.15, or $17.85 per acre.

Besides the first cost of water, namely, the expense of constructing ditches from the stream or the cost of shares in some irrigating canal, the irrigator must pay annually a small amount or must expend some labor in order to repair the ditches and keep them in good order, the amount being often only a few cents per acre. Where he takes water from some larger canal, especially one owned by a corporation, he may be compelled to pay a larger sum, that will not only cover the cost of keeping the canal in repair, but will also pay interest on the investment, salaries of officers, and other items of expense. In the aggregate this often amounts to $3 or even more per acre. Averaging all the statements as to the annual cost of water, the result for the entire arid and subhumid regions was $1.07 per acre.

Since the greater part of the irrigators owned the small ditches used for bringing water from the streams to the land, having built such ditches at points where the conditions were most favorable for construction and maintenance, the annual cost of keeping them in repair has been small, much less than it would have been under other conditions. For example, with the construction of larger irrigating works designed to carry water to land farther away from the streams and to overcome more or less serious obstacles, the first cost of irrigation was usually greater, as was also the annual cost, on account of the heavy interest upon the original investment, and also from the fact that salaries and other items of expense not entering into the operation of the small ditches were included.

The average cost of bringing the land under cultivation beyond the expense for water, but including fencing, was, according to the statements of the farmers, $12.12 per acre, ranging from $4.62 per acre in the case of the subhumid states to $17.48 per acre in California, the difference being due both to the configuration and character of the ground and to the amount of labor spent in preparing it for the various kinds of crops. For example, in most of the states where the cost of cultivation was low the ground originally was nearly barren, and there were no plants, except, perhaps, sagebrush, to be removed. In cases where the expense of preparing the ground for cultivation was great, either the ground was rough and uneven, requiring more or less leveling in order that the water might be applied economically, or it was covered with willows and other small trees, requiring considerable labor before the fields could be brought into arable condition. Where fruit trees and vines were to be planted great expense has often been incurred, especially in California.

TOTAL INVESTMENT AND ENHANCED VALUE.

By making use of the averages of cost and value as given in the preceding table and applying them, with proper modifications, to the acreage irrigated, it is possible to arrive at certain conclusions as to the amount invested in irrigation works and in lands cultivated by irrigation, also as to the value of the same and the enhanced value realized by the owners of lands and water rights. The results obtained are shown in round numbers in the three following tables. In the cases of Nevada and Wyoming a mean value has been substituted for the average first cost of water for each state, from the fact that the average first cost of bringing water to the land in Nevada, owing to peculiar circumstances, applied to the land which was under a comparatively high state of cultivation, and not to the hay lands, while in Wyoming the reverse was the case.

In the table on the following page, under the head of "Cost", is given the total first cost of bringing water to the land irrigated during the census year, that is to say, this is in round numbers the sum of the amounts obtained by multiplying the acreage irrigated by the average first cost of obtaining water, or of water rights, as given by the irrigators. It may also be considered as the investment in time and money in the construction of irrigating systems in use during the census year, under the broad assumption that each system was employed to its full capacity. In such cases, however, as those in which a canal furnished water to only a small proportion of the irrigable lands, only a portion of the total cost of the canal would be represented in the totals shown.

The total first cost of irrigating the designated land was for the entire arid and subhumid regions $29,611,000, this being the amount, as stated above, presumably invested in productive irrigation works. The total value of the works or of the rights thus created, assuming that the statements of the farmers apply to all cases, was $94,412,000, showing an apparent increase of $64,801,000, or 218.84 per cent. As to the total cost of the irrigation works or the expenditures for irrigation upon lands which for one reason or another were unproductive, it is impossible to obtain reliable estimates. Statements and conjectures have been made by interested parties, but they have no foundation so far as can be ascertained beyond the personal impressions of the individuals making the statements.

TOTAL APPROXIMATE COST OF PRODUCTIVE IRRIGATION SYSTEMS AND THEIR VALUE IN 1890.

STATES AND TERRITORIES.	Cost.	Value in 1890.	Increase.
Total	$29,611,000	$94,412,000	$64,801,000
Arizona	465,000	828,000	363,000
California	13,005,000	39,446,000	26,441,000
Colorado	6,369,000	25,350,000	18,981,000
Idaho	1,029,000	2,860,000	1,831,000
Montana	1,623,000	5,273,000	3,650,000
Nevada	1,251,000	3,714,000	2,463,000
New Mexico	512,000	1,679,000	1,167,000
Oregon	826,000	2,755,000	1,929,000
Utah	2,780,000	7,072,000	4,292,000
Washington	197,000	642,000	445,000
Wyoming	1,281,000	3,801,000	2,520,000
Subhumid region	273,000	992,000	719,000

The results shown in the foregoing table apply to irrigation constructions or rights considered apart from the land. As a matter of fact, in the vast majority of cases, it is practically impossible to separate land values in the arid region and assign to them a certain sum, for the value of the land is inseparably bound up with the question of water supply.

In considering what may have been the first cost of the irrigated land upon which crops were raised in the census year it is necessary to assume a sum representing the purchase price of the wild or desert land, the cost of bringing water to the land, and that of cultivating the soil, building fences, and performing other necessary operations. The following table gives in round numbers the acreage under discussion multiplied by the probable first cost of the three items per acre. It also shows the total value of this same land, as given previously, and the difference or increase in value to the farmer or owner of these irrigated areas. From the table it appears that the total first cost of this land, excluding the subhumid states, was $77,490,000, and the value, as derived from the statements of a majority of the owners, was $296,850,000, showing an increase of $219,360,000, or 283.08 per cent.

FIRST COST OF IRRIGATED AREAS IN THE ARID REGION, INCLUDING WATER RIGHTS, AND THEIR VALUE IN 1890.

STATES AND TERRITORIES.	First cost.	Value on June 1, 1890.	Increase.
Total	$77,490,000	$296,850,000	$219,360,000
Arizona	1,114,000	3,204,000	2,090,000
California	31,814,000	150,635,000	118,821,000
Colorado	16,140,000	59,696,000	43,556,000
Idaho	3,320,000	10,091,000	6,771,000
Montana	4,968.000	17,354,000	12,386,000
Nevada	3,905,000	9,200,000	5,295,000
New Mexico	1,701,000	4,677,000	2,976,000
Oregon	3,288,000	10,143,000	6,855,000
Utah	7,022,000	22,198,000	15,176,000
Washington	759,000	2,440,000	1,681,000
Wyoming	3,459,000	7,212,000	3,753,000

The total amount expended each year in maintaining systems of irrigation may be assumed, for purposes of comparison, to be represented by the total acreage irrigated multiplied by the average expenditure per acre as reported by the irrigators. This is given in round numbers in the table on the following page, and the total value of products as previously shown is placed in comparison with it. The difference represents a net value of products from the irrigated land, or the sum by which the irrigator must reimburse himself for his labor and expenses and for interest on the capital invested. This table shows that $3,794,000 was the probable amount expended during the census year at least for maintenance of canals and ditches, or 12.81 per cent of the amount previously assumed as the first cost of these systems.

TOTAL COST OF WATER AND OF MAINTAINING DITCHES IN THE ARID REGION IN 1889-1890, AND TOTAL VALUE OF PRODUCTS OF IRRIGATED LANDS IN 1889.

STATES AND TERRITORIES.	Total cost of water.	Value of products.	Difference.
Total	$3,794,000	$53,057,000	$49,263,000
Arizona	102,000	916,000	814,000
California	1,607,000	19,080,000	17,473,000
Colorado	704,000	11,686,000	10,982,000
Idaho	174,000	2,806,000	2,632,000
Montana	333,000	4,544,000	4,211,000
Nevada	188,000	2,899,000	2,711,000
New Mexico	141,000	1,174,000	1,033,000
Oregon	167,000	2,473,000	2,306,000
Utah	240,000	4,750,000	4,510,000
Washington	37,000	834,000	797,000
Wyoming	101,000	1,895,000	1,794,000

COST OF IRRIGATING CANALS.

Classifying irrigating canals and ditches according to their widths, it has been found that for those averaging less than 5 feet in width the expense of construction, including headworks, flumes, and other adjuncts, was $481 per mile; for those 5 feet in width and under 10 feet, $1,628 per mile; and for those 10 feet or more in width, $5,603 per mile. The greater number of the irrigating systems of the country have been constructed under such conditions that the owners can not give even an approximate estimate as to what they really cost. Many of them have been built by the efforts of a few farmers, acting originally in partnership, and have been enlarged from year to year as more land was brought under cultivation and population increased. Farmers as a rule have not kept account of the amount of labor or money expended on such works, and in cases where they owned the irrigating ditches they have not taken into consideration the labor expended upon the ditches at times when farm work was not pressing.

The average cost per mile of the three classes of irrigation works is given for each state and territory in the following table, which exhibits the variations in cost due to difference in topography, thoroughness of construction, and accidental circumstances. California heads the list as to cost. The differences in cost were due largely to the condition of development of irrigation, the states where the methods were crude and simple generally showing a less average expenditure, although the existence of one or two great works has introduced apparent departures from this rule.

AVERAGE COST PER MILE OF CONSTRUCTING IRRIGATING CANALS AND DITCHES

STATES AND TERRITORIES.	Under 5 feet in width.	5 to 10 feet in width.	10 feet and over in width.
General average	$481	$1,628	$5,603
Arizona	471	1,674	5,274
California	885	5,957	15,511
Colorado	380	1,131	5,258
Idaho	205	810	1,320
Montana	325	800	2,300
Nevada	200	1,150	....
New Mexico	310	581	6,066
Oregon	260	1,060	1,300
Utah	493	1,025	3,072
Washington	285	1,236	2,571
Wyoming	....	837	3,884
Subhumid region	303	447	1,884

WATER SUPPLY.

Facts concerning the water supply for irrigation have been ascertained in a general way by correspondence with irrigators and owners of canals and ditches, mainly by means of special irrigation schedules sent to all parts of the west. Obviously it is not possible in this way to obtain exact statements, for data as to the amount of water available or utilized for irrigation can be obtained only by means of measurements made by engineers skilled in such matters. The average irrigator has very indefinite notions concerning the amount of water flowing in streams, especially in those of considerable size, and in fact it is almost impossible for any person who has not made a specialty of such matters even to approximate such quantities with success.

As a general statement it may be said that throughout the arid region there is hardly a stream of small size from which water can be conducted readily upon arable land that has not been utilized to its full capacity during the summer season. To increase the area under irrigation it will be necessary either to use greater economy in employing the water, so that it will cover larger areas, or to store the flood and waste waters of the nonirrigating season. A great increase in the acreage cultivated can come also by the construction of expensive works to divert the water of large rivers upon lands which can not be watered except by the expenditure of a large amount of capital. Taking the country as a whole, there are very few localities, if any, where, as in the past, a farmer can divert water unclaimed by others, and by means of a simple ditch constructed by himself and his neighbors bring his farm under irrigation.

From the replies of irrigators throughout the country, it is apparent that in 1888 and 1889 there was a deficiency of water supply for the land then under cultivation along most of the streams. By a comparison of all the facts it is evident that, taking the past decade as a whole, there was an unusually large amount of water in the streams in 1885 and 1886, and that this amount decreased year by year, although by no means constantly in all localities. Thus it happened that while the area under irrigation was rapidly increasing, the water supply as a whole decreased, and during the years of drought, namely, 1888 and 1889, and in some localities 1890, there was a general loss of crops upon irrigated lands, due to the fact that a larger acreage was tilled than could be irrigated by the methods in use.

Not only was there loss of crops in many counties, but the areas which were irrigated and from which crops were obtained did not in many instances receive a sufficient amount of water to produce large or satisfactory results. Many statements have been made that, owing to insufficiency of water during the last part of the season, some of the cereal plants were cut for forage or were hardly worth the gathering.

The simple fact that the area which can be irrigated is dependent upon the amount of water flowing in the streams is often ignored in general discussions of irrigation and its possibilities. It is often taken for granted that because along some river there are vast areas of fertile land, some of which has been irrigated profitably, larger and larger areas will, with the progress of settlement, be brought under cultivation to an indefinite extent, the assumption being tacitly made that since the river drains a large area its waters must be proportionately abundant. It is unfortunately the case that many of the rivers of the arid region occupying a prominent place upon the map carry a very small amount of water for a part of the year, and this water is all utilized or needed for the land now wholly or in part under cultivation.

DUTY AND VALUE OF WATER.

The duty of water is the term used to express the relation between the quantity of water used in irrigation and the area upon which it is employed. If a given stream flowing at the rate of 10 second-feet irrigates throughout the season 1,000 acres, it is said that the duty of water is 100 acres to the second-foot. A second-foot of water is the quantity represented by a stream 1 foot wide and 1 foot deep flowing at the average velocity of 1 foot per second. The duty, as might be inferred, differs very widely with the character of the water supply, the methods of employing it, the character of the soil and crops, and perhaps more than all with the skill and experience of the irrigator. It is necessary, however, to assume certain averages in order to ascertain the value of flowing water.

The average duty of water most widely accepted is that originally taken by Powell (a) as 100 acres to the second-foot. In practice some irrigators undoubtedly reach a higher value and others a lower one. Throughout the arid region there is a popular expression of "1 inch to the acre"; that is to say, water flowing in a stream of moderate size will irrigate at the rate of 1 miner's inch to the acre. The miner's inch is a variable quantity, depending upon the method of measurement and the character of the aperture through which the water flows. In many of the states most of the details of measurement are defined by statute, but even then there is often uncertainty. For practical purposes, however, it may be assumed that in California 50 miner's inches equal 1 second-foot, and in Colorado and adjoining states 40 miner's inches, or even less, are equivalent to the same. This rate of 1 miner's inch to the acre, therefore, would give an extremely low duty of only 40 or 50 acres to the second-foot, but it is probable that in many localities where there is an ample water supply it is used as freely as this. The saying is so common that the majority of the irrigators who have formed any opinion on the subject have given this as the common practice. Nevertheless there can be little doubt that a higher duty is generally obtained.

Upon the new lands of Utah, Idaho, and Montana it is probable that the duty of water averages about 70 acres to the second-foot, and that it can be readily brought up to 100 acres. In California, in localities where water is scarce and great care is taken in using it, the duty has been found to be 200 acres or more, in exceptional cases rising to 500 acres or over, this high water duty being obtained usually in the case of orchards, in which the water is conducted by pipes to each tree. The state engineer of Colorado in the fifth biennial report estimates the duty of water of certain streams at from 168 to 424 acres per second-foot, using in this connection the acreage estimated by the water commissioners. By substituting the acreage from which crops were obtained as shown by this census,

---

a Report on the lands of the arid region of the United States, with a more detailed account of the lands of Utah, by J. W. Powell. Second edition, Washington, 1879, page 8.

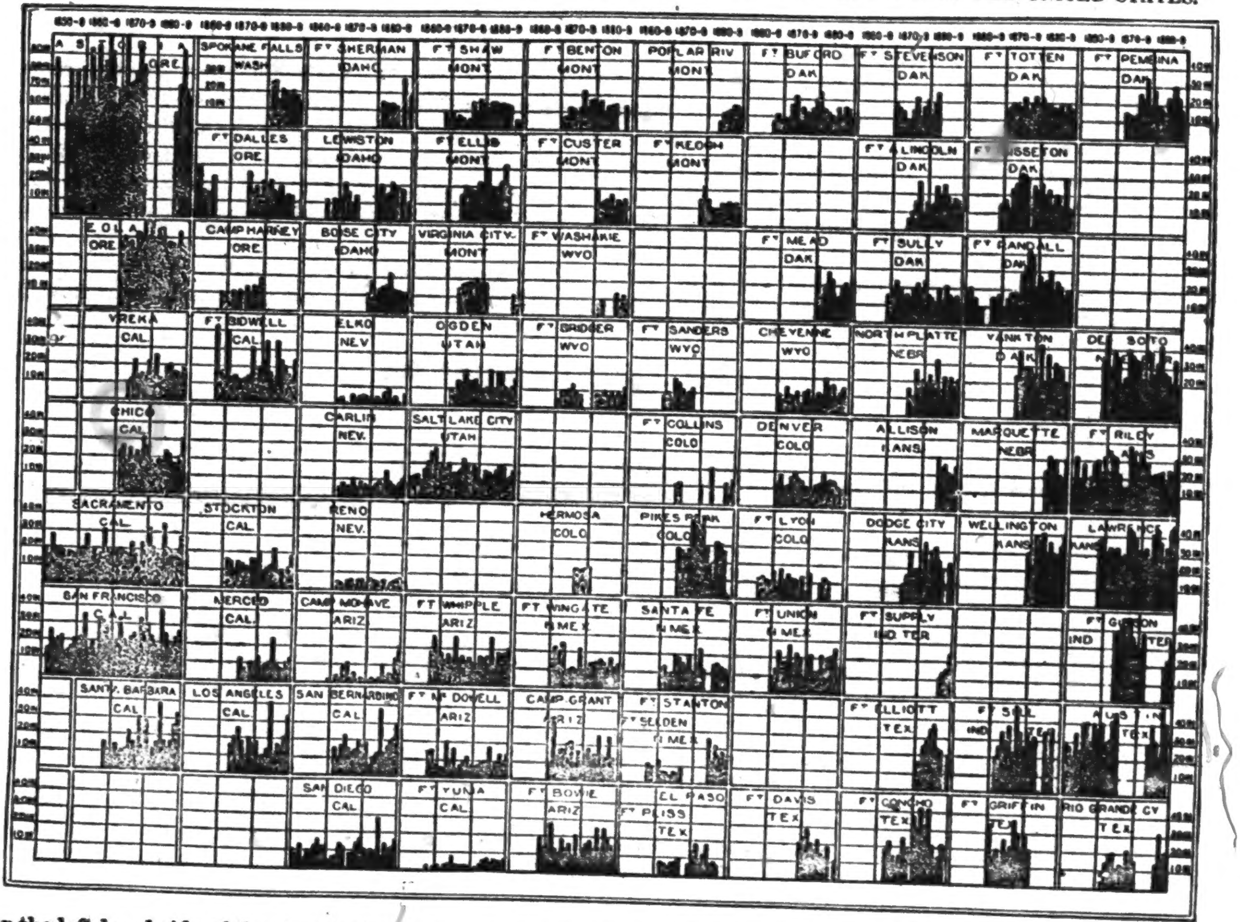
the duty has been found to be from 90 to 200 acres to the second-foot. This high duty of water is unquestionably due to the fact that some of the water returns by seepage to the stream and is used a second time. As a conservative estimate, as well as a convenient one, 100 acres to the second-foot may be considered as the average duty which has been obtained under favorable conditions and by the employment of ordinary skill on the part of the irrigator.

By taking a definite quantity to represent the duty of water, viz, 100 acres to the second-foot, and by ascertaining the average value of this water to the land, it is possible to obtain some conception of the value of the water resources of the country. Taking the average value of the water right as $26 per acre and the average first cost as $8.15 per acre, the difference, $17.85, can be considered as the value of the flowing water to each acre. If then 1 second-foot irrigates 100 acres, its value under these assumptions is $1,785. Thus, for example, a small river or creek carrying throughout the irrigating season 100 second-feet should be worth at least $178,500.

RAINFALL.

In any discussion of irrigation it is essential to make reference to the quantity and character of precipitation, for this governs not only the questions as to necessity of artificially applying water, but also throws some light upon matters of water supply. The data concerning rainfall have been so carefully collected and published by the United States Signal Service that it is sufficient to refer to its reports. In order to show in concise manner some of the principal facts several diagrams have been prepared giving graphically the annual and mean monthly rainfall at various points in the western half of the United States. The first of these, entitled "Annual rainfall at important stations in the western part of the United States", exhibits by a series of vertical lines the relative depth of rain at different points through a series of years. These are arranged in a rude geographic order, the stations given on the left hand side of the sheet being those near the Pacific coast and those on the right hand on the great plains of the Mississippi basin. The great fluctuations year by year are shown by the varying heights of these vertical lines or columns and also the irregularity or lack of uniformity. It is possible to pick out one or two years during which there was unusually large or small precipitation at most of the stations, but these are rather exceptional than

DIAGRAM OF ANNUAL RAINFALL AT IMPORTANT STATIONS IN THE WESTERN PART OF THE UNITED STATES.



otherwise. In 1884, for instance, the precipitation at a number of places was above the average and in 1885 less; but taken as a whole the plate illustrates the fragmentary character of even the best of the data and the great irregularity in annual rainfall.

The next plate, on the contrary, is characterized by a great uniformity, since it has been constructed from averages of from 15 to 20 years. It exhibits the average rainfall by months, the stations being arranged, as in the other plate, with regard to their geographic position. A prominent fact seen on this plate, as on the preceding, is the small amount of rainfall at the stations well within the arid region, but perhaps the most striking feature is the gradual change in distribution of rainfall throughout the year found in proceeding from one side of the diagram to the other. On the east, in the Great Plains region, the greatest rain occurs in the summer months, while in the west, near the Pacific ocean, the summer is the time of diminishing rainfall, succeeded by the annual drought. In the center, as, for example, at Fort Bridger, the rainfall is fairly evenly distributed or somewhat irregular. It is also interesting to compare the minimum rainfall shown at Yuma, Ariz., with that at Portland, Ore.

General A. W. Greely, Chief Signal Officer, has classified the distribution of rain according to months under a number of curves (*a*) typical of certain portions of the country. These curves, placed one above the other, bring out clearly the great difference in the distribution of precipitation between California and Colorado, and show that although in some points in California there may be a greater annual rainfall, yet the quantity of rain which falls during the summer is exceedingly small, and in order to save the trees and vines it becomes as necessary to irrigate as in regions of less annual precipitation.

In the present report, under the description of states, the quantity and distribution of the rain will be further discussed. Throughout the greater part of the arid region there have been relatively few points where rainfall measurements have been made, and these have been mainly in the vicinity of cities and towns of considerable size. Concerning the precipitation on the great mountain areas, from which the important streams come, little is known.

ARTESIAN WELLS.

A small amount of water used for irrigation is obtained from artesian wells, and therefore the census enumerators were instructed to include these within the agricultural schedule. By a tabulation of the returns it has been found that in the states and territories forming the western part of the United States there were 8,097 artesian wells upon farms in June, 1890. The artesian wells southeast of Minneapolis, supplying many cities and towns of Wisconsin and northern Illinois, as well as points more distant, do not enter into this discussion. The wells considered were in Kansas, Nebraska, North Dakota, South Dakota, Texas, and the states and territories west of them. Out of this total number of 8,097 wells, statistics concerning the depth, cost, discharge, and other features were obtained for 2,971, or 36.69 per cent. From this latter number of wells, fairly distributed in each state and county, averages have been drawn, which, when applied to the whole number, give the results shown in the following table:

ARTESIAN WELLS ON FARMS IN JUNE, 1890.

STATES AND TERRITORIES.	Total number.	Average depth in feet.	Average cost per well.	Average discharge in gallons per minute.	WELLS USED IN IRRIGATION.			
					Per cent.	Computed number.	Average area irrigated per well in acres.	Total area irrigated in acres.
Total	8,097	210.41	$245.58	54.43	48.54	3,930	13.21	51,896
California	3,210	248.00	425.00	164.00	64.17	2,060	18.63	38,378
Colorado	596	251.00	221.00	39.00	57.89	345	18.01	6,213
Idaho	28	83.00	53.00	11.00	50.00	14	13.21	185
Kansas	59	202.00	175.00	44.00	40.68	24	13.71	329
Montana	14	366.00	473.00	28.00	42.86	6	3.00	18
Nebraska	91	247.00	173.00	13.00	7.69	7	1.00	7
Nevada	33	215.00	607.00	6.00	60.61	20	1.00	20
North Dakota	461	196.00	265.00	21.00	2.17	10	2.00	20
Oregon	6	70.00	250.00	15.00	50.00	3	4.00	12
South Dakota	527	216.00	158.00	51.00	13.47	71	6.68	474
Texas	534	292.00	359.00	19.00	27.34	146	3.00	438
Utah	2,524	146.00	78.00	26.00	48.49	1,224	4.74	5,802
Washington	9	127.00	312.00	89.00	....	....	....	....
Wyoming	5	210.00	456.00	8.00	....	....	....	....

---

a Some of these are shown diagrammatically in his report upon irrigation and water storage, published as House Executive Document No. 287, Fifty-first Congress, second session

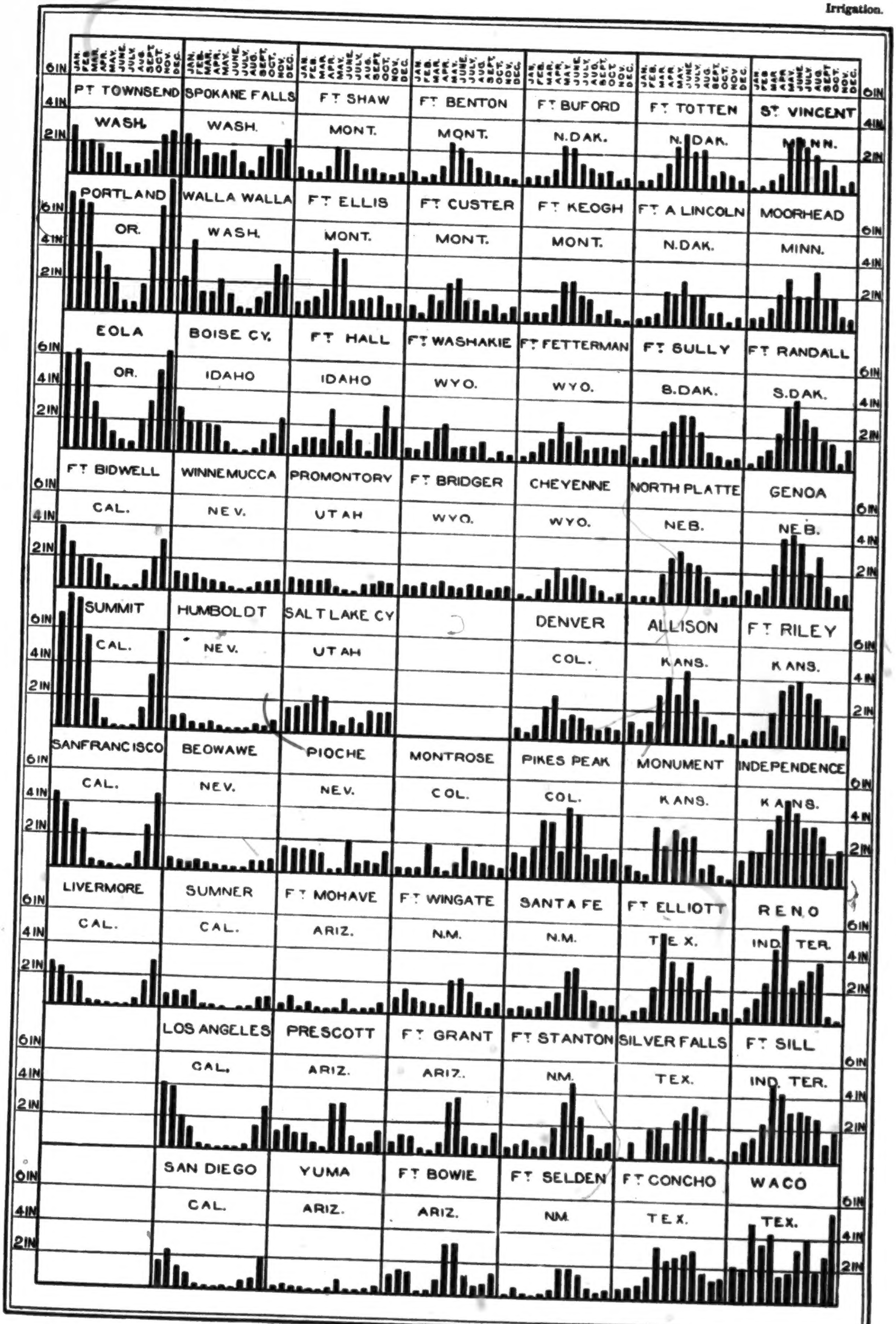


DIAGRAM ILLUSTRATING AVERAGE MONTHLY PRECIPITATION AT IMPORTANT STATIONS IN THE WESTERN PART OF THE UNITED STATES.

This table shows that 3,930 wells, or 48.54 per cent of the total number on farms, were employed in irrigation, watering 51,896 acres, or an average of 13.21 acres per well. Over one-half of these wells were in the state of California, irrigating 38,378 acres, or 73.95 per cent of the total area irrigated by flowing wells. The average discharge of the whole number of wells was 54.43 gallons per minute, or 0.121 cubic foot per second or second-foot. This gives a water duty of 1 second-foot to 109.17 acres; that is, the water flowing from these wells has irrigated on an average 109.17 acres per second-foot. The average depth of these wells was 210.41 feet, and the average cost was $245.58, or $1.17 per foot for all depths and conditions. Taking as the average discharge 54.43 gallons per minute, or 0.121 second-foot, the cost of the water would be $4.51 per gallon per minute, or $2,029.59 per second-foot. Taking the figures just given for the duty of water, namely, 1 second-foot for 109.17 acres, the average cost of irrigating an acre has been $18.59. The average cost of water per acre by ordinary means of irrigation, as derived from the statements of irrigators throughout the entire country, was $8.15, or 43.84 per cent of the cost by artesian wells. This, it should be borne in mind, is the average cost of water from successful wells. To arrive at the actual cost due allowance should be made for many attempts, aggregating perhaps thousands, to obtain flowing water without success. The total number of these can not be ascertained, for failures in this line are soon forgotten, but the amount expended annually by individuals, cities, towns, and corporations in fruitless attempts must be very large.

At an average cost of $245.58 per well, the 8,097 wells represent an aggregate investment of $1,988,461.26. The total depth drilled or bored in making these flowing wells was 1,703,689.77 feet, or 322.67 miles. The total amount discharged by all these wells was 440,719.71 gallons per minute, or 981.93 second-feet, nearly four-fifths of the discharge of the Rio Grande at Del Norte, Colo., for 1890, and a trifle less than that of the Weber river above Ogden, Utah, for the same year.

The amount of water discharged by artesian wells is so small that it has been found convenient to employ a smaller unit of measurement than in the case of rivers and creeks. The quantities in the latter case are usually expressed in cubic feet per second or second-feet. For artesian wells the far smaller unit often employed in regard to city supply, the gallon per minute, is used. A gallon per minute equals 0.002228 second-foot, and, conversely, 1 second-foot is equivalent to 448.831 gallons per minute, 1 cubic foot being equal to 7.48052 United States standard gallons. A third unit of flowing water is in popular use, namely, the miner's inch, but this, as previously stated, is an indefinite quantity, varying according to the method by which it is measured, in some localities 40 and in others 50 miner's inches making a second-foot. In this discussion the gallon per minute, since it is in common use, is employed.

An artesian well flowing at the rate of 100 gallons per minute, or 0.2228 second-foot, will in 1 day discharge 0.4419 acre-foot; that is, it will cover 0.4419 of an acre 1 foot in depth, or 1 acre that fraction of a foot in depth, and in 1 year will discharge 161.29 acre-feet. In other words, if all this water could be saved, this number of acres would be covered 1 foot in depth. At the average discharge of 54.43 gallons per minute a well during 24 hours discharges 0.2405 acre-foot, and in 1 year will discharge 87.79 acre-feet. All of the wells at this rate in 1 year would discharge a total of 710,835.63 acre-feet.

In the following table the number of wells in each county is given, together with the depth of the deeper and shallower wells, the average depth, cost, and discharge in gallons per minute of those wells for which statistics ~~were obtained~~:

ARTESIAN WELLS, DEPTH, COST, AND FLOW, BY STATES AND TERRITORIES AND COUNTIES.

CALIFORNIA.

COUNTIES.	Total number.	DEPTH IN FEET.			Average cost.	Average flow in gallons per minute.
		Shallow.	Deep.	Average.		
Total	3,210	....	....	248	$425	164
Alameda	34	40	450	195	401	62
Butte	3	....	....	800	2,000	4
Colusa	2	....	....	1,000	....	....
Contra Costa	1	....	....	....	....	1
Fresno	47	72	1,200	563	1,179	....
Inyo	1	....	....	20	....	....
Kern	89	300	1,100	551	1,489	1,072
Lake	45	50	100	81	90	59
Lassen	2	200	394	297	355	4
Los Angeles	627	20	600	187	394	192
Merced	112	170	700	326	431	65
Modoc	12	56	280	143	235	15
Monterey	60	60	189	136	152	3
Orange	649	26	450	147	209	110
Plumas	159	60	1,132	550	165	40

CALIFORNIA—Continued.

COUNTIES.	Total number.	DEPTH IN FEET.			Average cost.	Average flow in gallons per minute.
		Shallow.	Deep.	Average.		
Sacramento	4	....	....	75	825	....
San Benito	117	29	329	111	188	157
San Bernardino	301	65	700	191	493	283
San Diego	60	108	380	212	353	112
San Luis Obispo	11	74	124	101	84	4
San Mateo	50	80	252	170	505	108
Santa Barbara	22	75	147	112	112	7
Santa Clara	460	59	740	280	555	316
Santa Cruz	33	80	184	137	307	129
Shasta	1	....	....	209	543	4
Sierra	49	45	1,130	458	136	47
Siskiyou	1	....	....	700	1,500	133
Solano	1	....	....	250	....	....
Sonoma	2	76	315	195	532	6
Stanislaus	1	....	....	408	800	2
Tulare	139	50	1,080	587	1,362	409
Ventura	115	15	225	149	287	79

ARTESIAN WELLS, DEPTH, COST, AND FLOW, BY STATES AND TERRITORIES AND COUNTIES—Continued.

COLORADO.

COUNTIES.	Total number.	DEPTH IN FEET.			Average cost.	Average flow in gallons per minute.
		Shallow.	Deep.	Average.		
Total	596	....	....	251	$221	39
Arapahoe	185	136	858	400	420	13
Boulder	3	249	600	416	775	120
Conejos	184	40	478	146	70	23
Costilla	70	39	500	256	117	26
Douglas	5	....	....	....	....	....
Jefferson	7	....	....	558	1,100	....
Pueblo	2	....	....	772	1,800	....
Rio Grande	50	76	225	136	103	21
Saguache	90	110	426	267	265	140

IDAHO.

COUNTIES.	Total number.	Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	28	....	....	83	53	11
Bingham	15	90	150	120	37	13
Oneida	13	50	100	77	58	10

KANSAS.

COUNTIES.	Total number.	Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	59	....	....	202	175	44
Bourbon	7	163	620	442	753	14
Hamilton	6	....	....	275	400	20
Meade	44	50	210	153	46	49
Morton	1	....	....	700	825	30
Nemaha	1	....	....	14	20	....

MONTANA.

COUNTIES.	Total number.	Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	14	....	....	366	473	25
Cascade	2	....	....	160	350	6
Custer	12	....	....	400	488	26

NEBRASKA.

COUNTIES.	Total number.	Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	91	....	....	247	173	13
Cedar	36	255	550	388	261	14
Dixon	4	170	300	254	92	45
Holt	42	50	185	99	48	7
Knox	8	400	604	491	686	17
McPherson	1	....	....	28	35	....

NEVADA.

COUNTIES.	Total number.	Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	33	....	....	215	607	6
Churchill	2	....	....	300	1,750	7
Douglas	2	....	....	150	175	3
Lander	20	64	750	200	258	3
Ormsby	5	100	150	125	150	8
Washoe	4	....	....	....	....	....

NORTH DAKOTA.

COUNTIES.	Total number.	Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	461	....	....	196	265	21
Cass	100	35	514	169	235	6
Dickey	1	....	....	1,087	4,000	1,700
Grand Forks	20	40	217	142	205	34
Pembina	12	120	175	154	180	14
Ramsey	1	....	....	1,511	....	60
Richland	104	34	450	121	192	12
Sargent	3	125	610	367	962	1
Stutsman	1	....	....	1,523	....	167
Traill	170	96	440	212	277	11
Walsh	50	101	298	175	201	7

OREGON.

COUNTIES.	Total number.	DEPTH IN FEET.			Average cost.	Average flow in gallons per minute.
		Shallow.	Deep.	Average.		
Total	6	....	....	70	$250	15
Crook	2	....	....	104	150	....
Gilliam	1	....	....	21	....	10
Harney	2	....	....	....	....	....
Wasco	1	....	....	51	....	20

SOUTH DAKOTA.

COUNTIES.	Total number.	Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	527	....	....	216	158	51
Beadle	1	....	....	850	1,800	600
Bonhomme	6	512	736	655	1,172	219
Clay	150	205	500	311	120	55
Davison	10	97	288	172	188	3
Grant	12	30	117	59	33	17
Hanson	50	70	315	174	160	260
Hutchinson	11	3	154	83	92	26
Jerauld	2	....	....	799	625	3
Lincoln	12	32	70	47	23	3
McCook	11	85	195	133	105	41
Miner	66	60	284	133	94	16
Sanborn	92	60	600	110	124	89
Turner	30	24	340	82	47	18
Yankton	74	225	645	375	219	38

TEXAS.

COUNTIES.	Total number.	Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	534	....	....	292	350	19
Bandera	1	....	....	104	80	....
Bell	10	128	500	268	102	2
Bexar	10	....	....	575	600	100
Bosque	22	180	780	434	762	34
Brazos	15	228	470	330	407	4
Burleson	12	400	600	500	138	4
Burnet	2	87	97	92	92	1
Coryell	27	240	339	325	325	5
Dallas	66	65	262	153	209	3
Denton	32	134	684	350	387	3
Dewitt	6	55	100	67	88	11
Dimmit	10	98	165	151	284	2
Ellis	27	165	276	217	200	3
Galveston	5	....	....	400	800	40
Gonzales	3	....	....	284	548	2
Grayson	1	....	....	180	275	60
Hays	1	....	....	131	200	1
Hood	16	200	240	222	222	43
Jack	5	50	200	105	129	4
Johnson	8	70	272	171	106	20
Lavaca	1	....	....	435	1,700	24
McLennan	6	456	640	552	743	2
Palo Pinto	3	....	....	546	760	....
Parker	11	....	....	70	60	....
Reeves	1	....	....	185	350	60
Robertson	120	165	750	464	189	11
Somervell	48	93	350	211	221	36
Stephens	10	115	156	130	100	6
Tarrant	49	80	273	207	288	10
Uvalde	3	103	110	106	200	10
Victoria	3	825	946	896	2,333	120

UTAH.

COUNTIES.	Total number.	Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	2,524	....	....	146	78	28
Boxelder	34	54	203	115	53	27
Cache	73	33	410	157	112	12
Davis	492	30	425	160	76	29
Juab	7	85	90	88	93	93
Millard	26	132	250	153	83	4
Salt Lake	501	27	320	116	107	32
Sanpete	233	33	215	103	39	20
Sevier	14	60	100	60	31	11
Summit	1	....	....	165	150	....
Tooele	133	40	580	135	120	28
Utah	485	30	433	145	65	30
Weber	515	50	330	167	73	23

ARTESIAN WELLS, DEPTH, COST, AND FLOW, BY STATES AND TERRITORIES AND COUNTIES—Continued.

WASHINGTON.

COUNTIES.	Total number.	DEPTH IN FEET.			Average cost.	Average flow in gallons per minute.
		Shallow.	Deep.	Average.		
Total	9	....	....	127	$312	89
Spokane	1	....	....	130	230	14
Whitman	8	....	....	126	352	100

WYOMING.

COUNTIES.	Total number.	DEPTH IN FEET.			Average cost.	Average flow in gallons per minute.
		Shallow.	Deep.	Average.		
Total	5	....	....	210	$456	8
Albany	4	8	510	151	414	15
Sheridan	1	....	....	500	625	1

The artesian areas are widely scattered, and individually they are of small size, excepting those in North Dakota, South Dakota, and California, where the artesian conditions extend over several hundred square miles. Each of these areas will be discussed or mentioned in its appropriate place in the following pages.

By far the greater number of the artesian wells in the west have been put down within the last decade, there being comparatively few which have been in existence for 10 years. In California, however, cases are reported where wells have been flowing for 20 or even 30 years, the discharge not having decreased except through the interference of other wells. The success attained in sinking wells in some of the valleys of California and Colorado led to a widespread interest in such matters, and since 1884 attempts have been made to secure flowing water in the majority of counties of the western part of the United States.

Many cities and towns have devoted money to experimental drillings, and in a few instances state governments have favored such works by legislation or by direct appropriation. The national government in the early part of the past decade paid for the sinking of two wells upon the Great Plains, both of which were without success so far as flowing water was concerned. Perhaps the largest amount of experimental work has been done by railroads, whose need for pure water for locomotives has led to drilling a number of deep wells along their lines. Owners of cattle also, both as individuals and corporations, have spent large amounts of money in putting down deep wells in remote parts of the country in the hope of obtaining water for stock. In the aggregate a vast amount of experimental work has been done, and from the knowledge obtained in this way and by study of the geological structure the extent of conditions favorable for artesian wells is fairly well known.

The geological conditions favoring the existence of artesian wells are found in nearly every state considered, although in restricted areas. The most notable basins are in North Dakota, South Dakota, California, Texas, Colorado, and Utah; their importance as regards area and amount of water delivered being approximately in the order named. These areas, outlined by successful wells, are small compared to the total land surface of each state, a possible exception to this rule being in the case of North Dakota and South Dakota, where artesian water can apparently be obtained over perhaps one-fourth of these states, providing that wells are drilled to a depth sufficiently great.

Comparatively few artesian wells have been put down for irrigation alone, and the utilization of the water in raising crops has been what may be termed an afterthought of the owners. The greater number of the wells were drilled primarily for the purpose of obtaining drinking water, but since the amount consumed in this way must be small, even insignificant, the large surplus is available for other uses. Thus it is that, although the expense of irrigation from artesian wells is in many instances so great as to appear to be prohibitory, yet as other more important purposes are served and the water otherwise would be wasted, it results that irrigation by this method is profitable, especially for intensive agriculture.

The advantages of artesian water for irrigation lie mainly in the matter of convenience and independence of the owner. Having a well on his own land, subject to his exclusive control, the irrigator can employ the water when he pleases without waiting for his turn, as in the case of the farmer taking water from a company ditch. On the other hand, however, although he can obtain the water at all times, it comes, except in the case of a few remarkable wells, in a very small stream, so small that it requires great care and patience to conduct it from point to point. The dry soil drinks up this little stream with a rapidity almost as great as that with which it comes, so that many instances are reported where the farmer has been unable to carry the water more than 200 feet from the well. The temperature of the water, especially from the shallow wells, is usually low, from 40 to 50 degrees Fahrenheit, varying very slightly throughout the year. On a hot summer's day this water, if applied at once, might injure the vegetation.

For these reasons, namely, the small size of the stream and the low temperature of the water, it has been found advantageous wherever possible to build small reservoirs in which the water from the well can accumulate and become warmed by the sun. By this means a large quantity of water, warmed nearly to the temperature of the air, can be turned at once upon the fields in a stream sufficiently large to force its way from point to point, rapidly wetting the surface with comparative uniformity. In considering the cost of irrigation by artesian wells, therefore, the expense of constructing and maintaining a small reservoir should not be overlooked. Unfortunately, in many cases reservoirs are not feasible, either on account of peculiarities of the surface or because the water from the well does not rise to a height sufficiently great.

Artesian water is generally regarded as having less value for irrigation than water from rivers and creeks, from the fact that the latter usually contains a large amount of silt, which is believed to enrich the land. Well water, on the other hand, is almost always clear, although it sometimes carries a large amount of mineral salts in solution; the artesian waters ranging from those almost as soft as rain water to the strongest brine. When water, although containing but a small amount of saline matter, is used for irrigation, the salts left by evaporation gradually become concentrated, and may reach a point, especially if great care is not taken, where they completely destroy vegetation. This also is the case with many river waters, and may be obviated to a certain extent by thorough cultivation of the soil and proper management.

The majority of artesian wells are upon low grounds, the water only rising slightly above the level of the bottom lands of the valleys. This, as regards irrigation, is especially unfortunate, from the fact that these lower grounds are often below irrigating canals and are to a greater or less extent wet by the seepage from the canals or from the rivers. Wherever the pressure is sufficient to lift the water to lands upon the benches or sides of the valley above irrigating ditches the water has unusual value, but these cases are rare. In spite of this fact, however, flowing wells even in countries covered with a network of canals are valuable, from the fact that they furnish throughout the year a continuous supply of water suitable for domestic purposes and for cattle. During the winter time especially, when the water is turned out of the irrigating ditches, the artesian wells prove of great service.

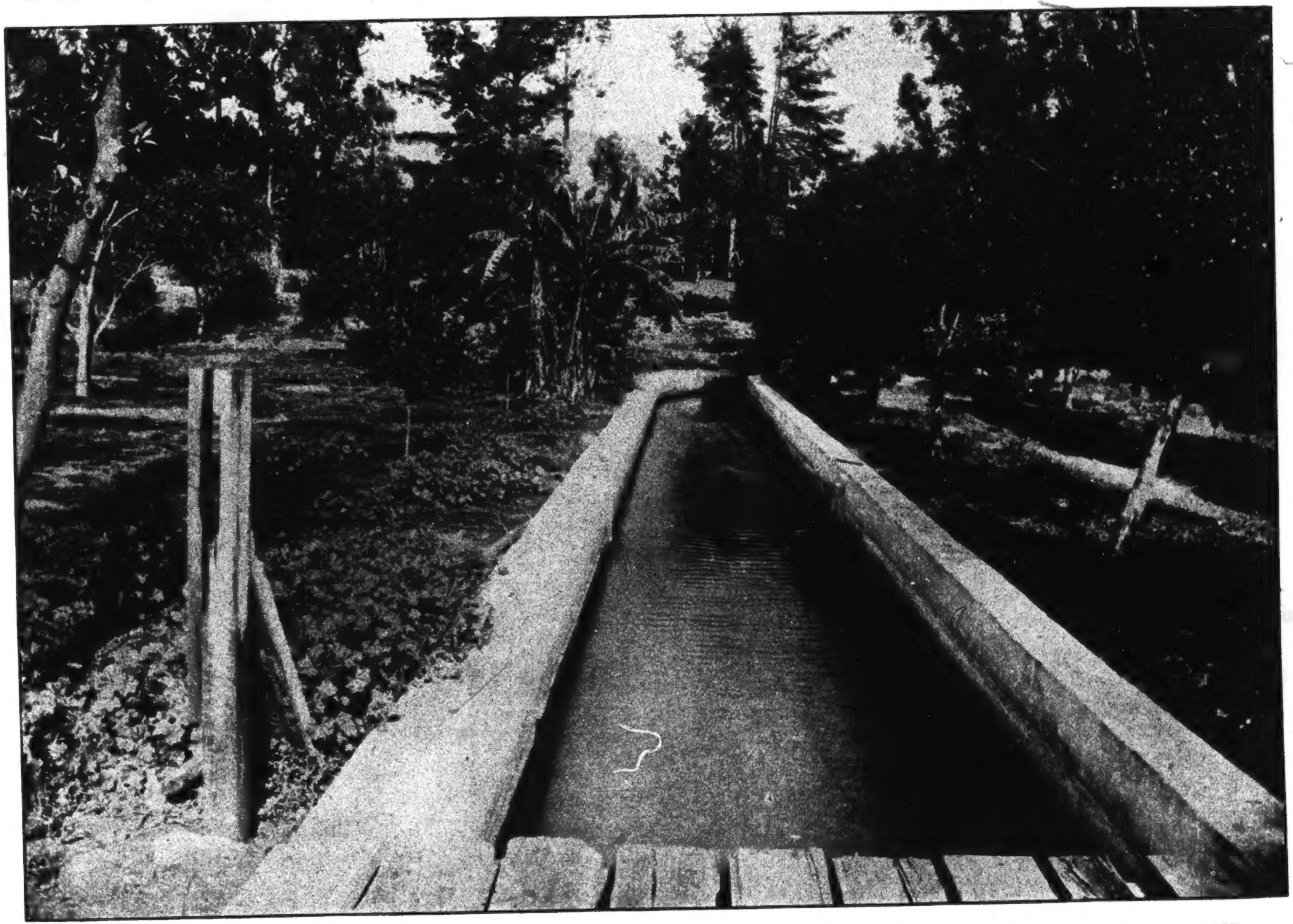
The development of the known artesian areas by the sinking of new wells has proceeded rapidly. The examination of statements from the owners of artesian wells demonstrates unmistakably, however, that the majority of wells show a gradual decrease in the amount flowing from them. Many wells do not exhibit a perceptible change in this regard, but the number in which shrinkage has occurred is sufficiently great to justify an examination into the causes prevailing in each basin or at each group of wells. This decrease in discharge has often resulted from mechanical imperfections in the construction of the well, which end in clogging or injury of the tubing or casing or in filling the lower part of the well with fine sand.

A more serious cause of diminution of flow is that due to loss of hydrostatic pressure resulting from an increase in the number of wells or from pumping one or more of them. The water in the pervious sands or gravels can never be completely exhausted by artesian wells or even by pumping, but it is comparatively easy to make the openings so numerous and large that water no longer has an opportunity of accumulating in the higher parts of the bed to an amount sufficient to exert great pressure at points lower on the dip of the beds.

Examples of the injury or even total destruction of artesian wells by increase in the number, or by reckless drilling through the confining strata, are to be seen in many parts of the country. The decrease of flow or complete stoppage of many wells of the Denver basin is well known. In California, along the coast south of San Francisco, are a number of small artesian areas where wells have been flowing for many years. The result of putting down new wells within the second half of the past decade has been that many of the older wells have stopped flowing except at times of high tide or during the rainy season. In fact, it is comparatively easy to find wells in any of the older basins which flow only during the winter. Legislative protection against interference with this valuable class of property is in many states essential in order to prevent its complete destruction.

The largest and probably the most permanent artesian areas of the country, namely, those of North Dakota, South Dakota, and Texas, lie east of the arid region and within that part of the debatable ground known as the subhumid, where irrigation is rarely necessary, although often of great benefit. On account of the fact that good crops are often raised by dependence upon rainfall, it has been difficult to convince the farmers within these artesian areas that irrigation can be made profitable or practicable from these wells. Even within the arid region few artesian wells have been put down by farmers primarily for irrigation, and it is doubted whether this can be profitably done except in instances where it has already been proved beyond a doubt by neighboring wells that a large artesian flow can be obtained. The risk and cost involved are often too great to justify the experiment. In unexplored territory the chances of striking flowing water are against the prospector, for even if the geological structure is favorable, the beds may be comparatively impervious to water, or it may not rise to the surface, or, as is often the case, it may be strongly saline. The expense of maintenance also in the case of wells delivering pure water is occasionally a notable amount, owing to the necessity of keeping them clean or of repairing accidental injuries.

The efficiency for irrigation of the water from artesian wells varies widely with the character of the crops, soil, and climate. The greater part of the water is used upon small gardens in the vicinity of houses, and for fruit and shade trees, for watering lawns, and for raising grass either for pasturage or for hay. Toward irrigating the ordinary field crops, such as wheat, rye, oats, and corn, water from this source has been employed to only a small extent. As will be seen by examining the figures previously given, the number of acres irrigated per well in each



VIEW OF CEMENT LINED CANAL NEAR SANTA ANITA, LOS ANGELES COUNTY, CALIFORNIA, ILLUSTRATING IMPROVED METHOD OF CONDUCTING WATER.

state is by no means proportional to the discharge. In California and Colorado, for instance, approximately the same number of acres per well are irrigated, although in the case of the former the average discharge is over four times as great as in the latter. This difference is traceable to the character of the soil and surrounding circumstances, the discrepancy arising from the fact that in the San Luis valley in Colorado the wells irrigated large areas of land in the immediate vicinity of canals, where the ground water stood comparatively near the surface, and thus the small amount from an artesian well was very effective, while in some of the other states the ground in the vicinity of the well was dry to such depths that it drank up the water with astonishing rapidity.

RESERVOIRS.

In various parts of the country attempts have been made to increase the amount of water available during the irrigating season by means of storage works holding a portion of the flood waters until most needed. Great interest has been shown in the development of these works, and their necessity is attested by the popular discussions of the advantages to arise from their construction. There is hardly a county in the whole arid region in which there are not a number of sites at which it has been proposed at one time or another to construct a reservoir. Unfortunately, however, experience has proved that the natural advantages for the profitable construction of storage reservoirs are not widely distributed, and there are few places in any one state where under present conditions it will pay to hold water. As a usual thing the localities pointed out are deficient in storage capacity or are so located that a perfectly safe dam can not be constructed with reasonable outlay. Progress therefore in the increase of water supply by this means has been and must continue to be slow, relative to the development of systems for distributing water. In certain parts of the country, for example, in Colorado, many small reservoirs have been built by farmers for the purpose of holding water for individual use, but the aggregate capacity of these is almost insignificant.

The best known storage works of the country are probably the Sweetwater reservoir of the San Diego Land and Town Company; the Cuyamaca reservoir of the San Diego Flume Company; the Bear Valley reservoir, belonging to the Bear Valley Company (these three being in southern California); Lake Yosemite, near Merced, Cal., and the Castlewood reservoir, near Denver, Colo. In addition to these there are a number of other works in process of construction or projected, notable among these being the Hemet Valley dam, the Arrowhead works of southern California, and the Pecos dam, in southern New Mexico.

Besides the reservoirs mentioned above, which are wholly artificial, there are throughout the west a number of lakes used to a certain extent as storage works. In the case of the larger of these lakes the natural fluctuations of water level are almost beyond control, and the evaporation from the surface is usually far greater than the amount of water utilized. The largest of these are Utah lake, in Utah; Bear lake, in Utah and Idaho; Lake Tahoe, in California and Nevada; Clear and Eagle lakes, in California. It is probable, also, that Goose lake, in Oregon and California, could be used, as well as Klamath lake, by the construction of suitable outlets. A comparison of these large bodies of water with the wholly artificial reservoirs is hardly possible, since the area of the former is nearly 100 times as great.

METHODS OF CONDUCTING WATER.

Water is usually brought from the running stream or reservoir by means of open ditches or canals built on a grade such that it shall flow freely. Many considerations have to be taken into account in determining the fall of the ditch. As a general rule, the less the grade the more land the ditch will command at a given number of miles from the head, but, on the other hand, a canal of gentle grade requires a larger cross section than one of more decided slope, and if the velocity of the water is small the channel may be entirely choked by aquatic plants. Too great a slope, however, results in the washing away of the banks and bed, requiring constant care and expenditure. Little attention was given to details of this kind in the laying out of the older ditches and canals. As experience has been gained and larger and more expensive enterprises have been entered upon, engineering skill has been called into practice, and the open channels and flumes have been improved upon in various ways. In many instances the open earth ditches have been replaced, in whole or in part, by conduits less wasteful of water. In southern California especially, where, owing to the absence of frost, there is less liability of destruction, cement has been largely used in various ways. For example, some of the open ditches have been lined with stone and a coating of cement placed upon this, making the sides and bottom of the ditch smooth and impervious, thus at the same time increasing the capacity while diminishing the loss by seepage.

In various parts of the country pipes of wood or of iron are being employed to a considerable extent to prevent loss of water, especially at points where it is difficult to maintain an open channel. The wooden pipes are made of strips of plank, with their edges carefully beveled or fitted together. These strips run lengthwise of the pipe, and no two terminate at the same point, so that the pipe when complete is practically continuous. The pieces are bound together and held in place by iron hoops at short intervals. The iron pipes generally employed are made of sheet iron put together in various ways, usually, however, in short lengths. Many styles of pipe are on the market, as single and double riveted, spiral, double cemented, and coated. Cast iron is used to only a small extent, owing to its heavy cost. Where frosts are not feared cement or stoneware pipes are often employed, especially in connection with the cement ditches mentioned above, the water in these pipes being submitted to slight pressure. Taking the arid region as a whole, however, the open earth ditch is the rule and such devices are exceptional, marking perhaps the beginning of better things.

METHODS OF APPLYING WATER.

The methods of applying water to the soil in use in different parts of the arid region depend largely upon the character of the soil and crop, the quantity of water usually available, the slope of the ground, and the degree of skill on the part of the average irrigator. The grasses and other forage crops, notably alfalfa, when growing upon nearly level ground, are usually flooded by cutting the side of the distributing ditch, constructed along the highest parts of the field. The opening in the side of the ditch is usually made by a shovel or hoe, and is filled in again after the adjacent portion of the field has been irrigated. Sometimes, however, small gates or openings through the side of the ditch provided with suitable sliding doors are placed permanently, so that the quantity of water can be regulated with some degree of care. From the openings in the side of the ditch the water is allowed to find its way in all directions, and unless the surface is perfectly level some portions receive far more than others. Thus fields slightly undulating will often show bare spots where the plants have not received sufficient moisture. Where the supply of water is ample, especially on the edge of some broad valley, enormous areas of the native grasses are thus flooded, little care being taken to distribute the water evenly, since the yield per acre is at best small.

On very gently sloping lands what is known as the check system has been largely in use, especially in California. This consists in raising low ridges of earth, about 1 foot in height and 10 feet or more in width at the bottom, these being built along contours and thus meandering across the fields as required by the slope of the ground. The space between the distributing ditch and the first check or small levee, which may be at a distance of from 100 to several hundred feet, is first filled with water, and the soil being saturated the low levee is cut in one or more places and the surplus water, together with an additional supply from the distributary, is allowed to fill the second checks or levees. These checks are so broad and low that they do not interfere with cultivation, the farming machinery passing over them without difficulty. Among the Mexicans this system of checks is carried to an extreme. They are placed very near together and consist of sharp, narrow ridges, inclosing patches of grain or vegetables often not more than 20 feet square. Each of these in turn is made into a pond by turning water in from the nearest ditch.

The cereals and other field crops are irrigated by means of furrows, whose distance apart varies with the character of the soil. In Utah and many other parts of the arid region, after the grain is planted, what is known as a marker is run over the field, rolling or digging small furrows 18 inches to 2 feet apart, through which the water is allowed to flow two or three times during the growing season. Vegetables and corn are wet by turning water into the furrows between the hills or rows, these having previously been plowed in a direction such that there shall be a continuous gentle fall from the distributing ditch to the far end of the field. The irrigation of plants on land having a decided fall requires considerable care and skill on the part of the farmer in order to prevent the washing away of the soil and the unequal distribution of water. For this end furrows are plowed, winding along the ground in such a manner as to reduce the fall, and small quantities of water are used at a time in order that it may not break away and cut channels down the slopes. For fruit trees and vines the water is usually applied by furrows; the water seeping from these furrows saturates the soil uniformly, and the quantity is easily regulated.

In many cases steeply sloping lands which have been considered as useless for agriculture have been found to possess a soil and climate especially adapted to fruit culture. These lands have in many instances been terraced and the water allowed to flow in channels along each of the benches thus made, erosion being prevented by conducting the water from terrace to terrace by wooden, metallic, or stone conduits. The fruit trees receive moisture by percolation from the channels or furrows or by the complete saturation of the surrounding soil from small pools formed on the surface. This latter method of applying water has been largely practiced by fruit growers, but is perhaps falling into disuse. It consists in surrounding each tree with a ridge of earth, forming a basin, into which water is let from the distributing ditch. This basin system, which is similar to the methods practiced by the Mexicans, is used either upon sloping or level ground. Among the disadvantages of the use of basins are those arising from the fact that the high ridges render cultivation difficult and expensive, and from a tendency to apply too much water to a restricted area. For these reasons orchardists are gradually learning to apply water by means of furrows, which can be quickly made after each cultivation.

In order to reduce the length of these furrows and to conduct the water with as little loss as possible, small wooden flumes, placed on or above the ground, are sometimes built through an orchard leading from the distributing ditches to the furrows. In this flume openings 1 inch square are cut at intervals of from 2 to 5 feet or more, each of these being closed by a small metallic slide. When ready to irrigate, the small flume is filled with water,

VIEW OF ORANGE ORCHARD, SHOWING METHOD OF APPLYING WATER BY BASINS ON TERRACES.

and a number of the small shutters are drawn out, allowing the water to escape into furrows, which in turn conduct it to the trees or other plants. These wooden flumes can be laid on uneven ground or carried over steeply sloping surfaces by introducing vertical drops from time to time, thus making it possible to irrigate the hillsides.

The most economical method of distributing the water applicable in the case of orchards and vineyards is that by means of pipes laid under ground. This is, of course, very expensive, and can be only adopted where the value of products is high, as in the case of citrus and other fruits. Attempts have been made to deliver water to trees and vines through porous earthenware pipes, but this, though theoretically perfect, in practice has not been successful, owing to the clogging of the pipes by roots and other causes. Where water is brought to each tree or group of trees by means of pipes it is customary to provide a small hydrant, through which water rises to the surface and is conducted away over a small adjacent area.

ARIZONA.

Total population (average per square mile, 0.53)		59,620
Number of owners of farms (2.39 per cent of population)		1,426
Number of irrigators (75.39 per cent of farm owners, 1.80 per cent of population)		1,075
Area of territory, land surface (112,920 square miles)	acres..	72,268,800
Area irrigated in census year	do...	65,821
Area of all farms, 8.03 per cent improved	do...	1,297,033
Cereals raised in census year, including 29 acres in rye	do...	22,701
Barley, average production 23.77 bushels per acre	do...	10,644
Corn, average production 19.06 bushels per acre	do...	4,331
Oats, average production 23.10 bushels per acre	do...	1,472
Wheat, average production 16.12 bushels per acre	do...	6,225
Alfalfa	do...	19,945
Total value of all farms, including land, fences, and buildings		$7,222,230
Estimated total value of the irrigated farms, as above		$3,204,000
Estimated value of all farm productions (sold, consumed, or on hand) for 1889		$1,045,970
Estimated value of production, as above, from farms irrigated in whole or in part		$916,000
Average size of irrigated farms	acres..	61
Average size of irrigated farms of 160 acres and upward	do...	287
Per cent of acreage of irrigated farms of 160 acres and upward to total acreage irrigated		34.42
Average size of irrigated farms under 160 acres	acres..	43
Average first cost of water right per acre		$7.07
Average annual cost of water per acre		$1.55
Average first cost per acre of preparation for cultivation		$8.60
Average value of irrigated land, including buildings, etc., in June, 1890, per acre		$48.68
Average annual value of products per acre in 1889		$13.92

The above table gives in condensed form the principal statistics concerning irrigation in Arizona, showing its importance to agriculture and affording a means of comparison with other branches of industry. In order to make plain the development of irrigation in this territory relative to that of other great political divisions, it should be stated that the assumption has been made that the arid regions are bounded by certain arbitrary lines, embracing Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, 16 eastern counties of Oregon, Utah, 13 eastern counties of Washington, and Wyoming. As a matter of fact, however, portions of the areas above named are far from being arid. On comparison with these states and territories it appears that in number of irrigators and in acreage irrigated Arizona in 1889 stood next to the bottom of the list, coming above Washington, this latter state having the least number of irrigators and the smallest area irrigated. In average size of irrigated farms it was sixth, in this respect standing between California and Oregon. In average value of products per acre in 1889 it was number 4, California, Utah, and Washington exceeding it.

In comparing the areal extent of irrigation it appears that a smaller proportion of the entire territory was irrigated (less than one-tenth of 1 per cent of the entire land surface) than in any other state or territory. This is because Arizona embraces an enormous extent of the deeply eroded plateau country traversed by the Colorado river and also of the desertlike region adjoining the republic of Mexico, both of which areas are almost uninhabitable. Although the number of farms and of irrigators was small, yet, the proportion of farms irrigated was large, 75.39 per cent of the total number using water. In this respect Arizona stood third, Utah and Nevada exceeding it. On the other hand, in comparing the extent to which irrigation was practiced on these farms and the relative area actually irrigated, Arizona stands at the head of the list, 43.21 per cent of the total farm area owned by irrigators being irrigated, a percentage over twice as great as that prevailing throughout the arid region. In average value per acre of land irrigated, including improvements, $48.68 per acre, Arizona was number 8, while, as previously stated, in average value of products, $13.92 per acre, it was number 4. In first cost of water rights the territory was fifth, and in average annual cost of water per acre, $1.55, it was second, being exceeded only by California.

By reference to the map of the western part of the United States it will be seen that the irrigated areas lie mainly in the central and southwestern half of the territory. The high plateaus of the northern part of the territory are bounded by a series of great escarpments, the face of these extending diagonally across the center of the territory and facing the plains of the Gila basin. The winds from the west sweeping across the low plains are deflected upward by the abrupt slopes and mountain masses bordering the plateau, and a portion of their moisture is precipitated, forming almost innumerable creeks which unite to form the Verde, Salt, and other tributaries of the Gila, and thus render possible a large amount of irrigation in the valleys, especially on the Gila and Salt plains near the point where the waters leave their canyons. On the edge of the plateau country and among the mountains at elevations of from 6,000 to 8,000 feet, agriculture is successfully carried on without irrigation, in connection usually with stock raising or in the immediate vicinity of mining towns. For the greater part of the territory, however, it may be said that irrigation is practiced or needed during the entire year. In the lower lying plains the temperature is such that crops grow and mature at any season, providing there is a supply of moisture. Crop follows crop in succession, depending only upon the abundance or scarcity of water in the ditch or of the summer rains. During the winter and in the early spring and late fall the water is used on the alfalfa and hay crops, of the former of which from 3 to 6 cuttings or even 7 are made, the average number for the whole territory being 5. Usually two waterings are given for a cutting, and thus the total amount of water used is in excess of that required by any other crop. Later in the spring, when the rivers begin to decline and the water supply becomes scanty in most ditches, the alfalfa is neglected, all the water being needed for other crops, and still later, before the floods begin, in many places the whole flow is employed upon the trees and vines.

The water is applied in most cases by flooding, as, for instance, on lucern and grain, or through furrows laid off at regular intervals, no especial care being taken in the preparation of the fields. The Mexicans still practice the old method of flooding in small "pools" or rectangular areas separated by ridges of earth. The farmers in many localities look forward to better methods of distributing and applying water. Since the soil and local conditions vary so widely, there is no rule as to the number of waterings or time required for the different products. There is a general impression that in many cases too much water has been used and that in the future better crops can be matured by using the water more sparingly, as a result increasing the acreage. Shortage of water and loss of crops on irrigated land were reported by many of those whose rights to water were secondary to those of older claimants. The latter stated that as a rule there was ample water for their needs, excepting from the middle or latter part of June through July, August, and into September. Many of the field crops should have matured before this time, so that what little water remained could be used for orchards, vineyards, and alfalfa. The improved lands of the territory are too valuable to be given up to the ordinary field crops and cereals, but could be utilized to a greater extent in the production of high grades of semitropic fruits or of plants which, while flourishing in Arizona, are less successful elsewhere. Especially is this the case if water storage is to be utilized to any great extent, for the capital invested in such enterprises must necessarily be so great that the ordinary field crops can hardly be remunerative. Many projects of this character are on foot, but progress has been slow, since large capital is required, and there has been very little definite information upon which to base engineering computations.

DEEP WELLS.

In this territory no flowing wells were reported upon farms in June, 1890. Deep wells have been drilled in various places, but so far as reported without success. At Phenix a well has been drilled to the depth of 700 feet, and on the plains of the Gila water at various depths has been sought. On the road between Mesaville and Florence is a well several hundred feet in depth, from which water is drawn by horse power. In the Verde valley, in the central part of the territory, it is claimed there is a flowing well, but the facts concerning it have not been ascertained.

Near Pima, in Graham county, a well was drilled to the depth of 420 feet without success, and in Pima county, at Calabasas station, a well is said to have been drilled 700 feet, but no water ever flowed from it. At various points along the Southern Pacific railroad are comparatively deep wells, from which water is pumped by steam or by windmills. At Yuma are wells from 75 to 100 feet in depth, pumped in this manner, the water being used to a very small extent for irrigation. None of these wells flow, but it is reported that in one case at least the water comes to within 20 feet of the surface.

RAINFALL.

The table on the following page gives the principal data concerning the amount and distribution of precipitation in Arizona. It shows the mean monthly and annual rainfall at stations where measurements have been made for two years or more. (*a*) According to this table the mean annual rainfall at stations in the territory varied from 3.06 inches at Yuma up to 25.57 at Goodwin, in Graham county, a number of localities in the mountains showing a mean annual rainfall of 20 inches and over.

---

a Report by the Chief Signal Officer of the army (Fifty-first Congress, second session, House of Representatives, Executive Document No. 287, Irrigation and Water Storage in the Arid Regions, February 28, 1891).

MEAN MONTHLY AND ANNUAL RAINFALL AT STATIONS IN ARIZONA.

[T. indicates a trace of rain, less than 0.01 inch.]

LOCALITIES.	Altitude in feet.	Length of record.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Apache county:		Yrs. Mos.													
Holbrook	5,047	3 10	0.54	0.71	0.72	0.67	0.16	0.12	1.51	1.40	1.18	0.68	1.08	0.72	9.49
Fort Apache	5,050	18 10	1.34	1.80	1.65	0.84	0.47	0.72	4.04	4.20	1.54	1.34	1.17	1.93	21.04
Fort Defiance	6,500	a9 2	0.98	0.70	0.84	0.67	0.52	0.72	2.44	2.73	1.86	0.70	1.16	0.87	14.19
Cochise county:															
Wilcox	4,164	a9 9	0.89	0.90	0.92	0.08	0.12	0.21	2.37	2.70	1.21	0.67	0.44	0.84	11.35
Benson	3,580	9 10	0.50	0.45	0.51	0.02	0.09	0.29	1.77	2.23	0.71	0.50	0.24	0.75	8.06
Fort Bowie	4,781	23 2	1.11	1.77	1.27	0.19	0.28	0.69	3.28	2.90	1.34	0.57	0.74	1.27	15.41
Fort Huachuca	4,785	4 8	0.80	1.27	0.97	0.11	0.15	0.39	4.29	2.92	2.61	0.94	1.02	0.95	16.42
San Simon	3,611	a8 5	0.27	0.28	0.53	0.02	0.11	0.04	0.55	1.64	0.22	0.30	0.24	0.30	4.50
Gila county:															
Fort San Carlos	3,456	a9 3	1.22	1.63	1.38	0.31	0.22	0.24	1.85	2.43	0.91	0.75	0.67	1.85	13.46
Graham county:															
Fort Thomas	2,700	10 6	0.84	1.18	1.08	0.35	0.45	0.26	2.03	2.31	0.93	0.63	0.48	1.30	11.84
Camp Goodwin	2,650	a3 11	2.41	1.82	1.04	1.30	T.	0.59	3.35	5.78	3.90	1.39	1.18	2.81	25.57
Fort Grant	4,860	a17 2	0.92	1.24	1.13	0.38	0.29	0.65	3.86	3.22	1.84	0.94	0.86	1.52	16.85
Maricopa county:															
Fort McDowell	1,250	a23 10	1.06	1.24	0.74	0.42	0.13	0.12	1.26	1.48	0.94	0.42	0.81	1.76	10.38
Phenix	1,068	12 9	0.56	0.87	0.67	0.32	0.12	0.09	0.73	1.02	0.65	0.57	0.54	1.25	7.39
Burkes	....	3 0	0.10	0.68	0.18	0.11	0.07	T.	0.02	1.44	0.57	0.02	0.41	0.28	3.88
Wickenburg	1,400	a8 1	1.07	1.10	0.80	0.52	0.30	0.02	0.81	1.99	0.66	0.18	0.51	1.89	9.85
Pima county:															
Fort Lowell	2,400	a19 5	1.14	1.15	0.83	0.28	0.10	0.30	2.47	2.79	1.38	0.45	0.52	0.96	12.37
Fort Buchanan	5,330	3 11	1.47	1.51	0.20	0.60	0.14	0.82	5.25	6.16	2.03	1.16	1.09	1.15	21.58
Camp Crittenden	2,000	4 10	0.55	1.09	0.65	0.26	0.05	0.31	6.01	4.70	0.85	0.19	0.28	1.57	16.51
Pinal county:															
Breckenridge	3,800	a6 10	1.00	0.76	0.45	1.21	0.10	0.50	4.64	4.08	1.95	0.06	1.19	1.09	17.03
Maricopa	1,190	13 8	0.44	0.46	0.69	0.14	0.07	0.06	0.40	0.91	0.47	0.34	0.35	0.84	5.17
Yavapai county:															
Camp Date Creek	3,726	a6 3	0.92	1.58	0.95	1.03	0.13	0.24	3.19	3.39	0.29	0.46	0.64	1.40	14.22
Whipple Barracks (Prescott)	5,389	23 11	1.45	1.78	1.66	0.98	0.58	0.17	3.03	2.88	1.18	0.66	0.82	1.65	17.06
Yuma county:															
Yuma	141	14 11	0.39	0.45	0.18	0.12	0.06	T.	0.13	0.40	0.13	0.21	0.35	0.64	3.06
Texas Hill	355	a11 0	0.58	0.27	0.27	0.10	0.03	....	0.08	0.45	0.34	0.61	0.26	0.48	3.47

a Record broken.

CONDITION OF IRRIGATION IN EACH COUNTY.

The following table gives some of the fundamental data of irrigation during the census year in each of the counties of the territory. Upon an examination of the figures it will be noticed that in general the value of products per acre increased as the average size of farm diminished. For example, in Maricopa county the average size, 108 acres, was the greatest in the territory, while the value of product, $9.26 per acre, was the least. Next comes Yuma county, with 93 acres per farm and products averaging $10.50 per acre, then Pinal, with 60 acres per farm and products of $11.25 per acre. In other words, the large irrigated farms were not as closely tilled as were the smaller, and a lower priced crop resulted.

NUMBER OF IRRIGATORS, AREA IRRIGATED, FARMS, AND CROPS IN EACH COUNTY IN ARIZONA IN 1889.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.	OWNERS OF FARMS. (a)		IRRIGATORS.		Area of county in acres.	FARM AREA.		Cereals in acres.	Alfalfa in acres.	AREA IRRIGATED.			Average value of products per acre.
				Total number.	Per cent of population.	Per cent of farm owners.	Per cent of population.		Acres.	Per cent improved.			Per cent of area of county.	Per cent of total farm area.	Per cent of land owned by irrigators.	
Total	1,075	65,821	61	1,426	2.39	75.39	1.80	72,268,800	1,297,033	8.03	22,701	19,945	0.09	5.07	48.21	$13.93
Apache	182	5,545	30	253	5.91	71.94	4.25	13,478,400	1,085,535	0.73	3,693	856	0.04	0.51	32.56	13.38
Cochise	52	2,372	46	192	2.77	27.08	0.75	3,842,560	31,513	19.65	242	614	0.06	7.53	31.75	26.93
Gila	18	815	45	18	0.89	100.00	0.89	2,055,680	3,080	22.53	375	23	0.04	26.46	26.46	23.85
Graham	199	7,556	38	201	3.54	99.00	3.51	3,937,280	23,533	38.55	4,823	1,741	0.19	32.11	37.38	16.06
Maricopa	327	35,212	108	336	3.06	97.32	2.98	6,330,880	61,888	78.79	9,216	12,198	0.56	56.90	60.14	9.26
Mohave	....	....	....	14	0.97	....	....	7,252,480	1,781	21.45	10	202	....	....	....	....
Pima	85	3,085	36	114	0.90	74.56	0.67	6,781,440	31,852	16.24	643	891	0.05	9.69	33.17	30.38
Pinal	115	6,919	60	124	2.92	92.74	2.71	3,392,000	20,804	40.39	2,666	1,534	0.20	33.26	37.09	11.25
Yavapai	91	3,762	41	161	1.85	56.52	1.05	18,711,040	32,417	52.34	1,026	1,716	0.02	11.61	26.22	31.00
Yuma	6	555	93	13	0.49	46.15	0.22	6,487,040	4,630	12.63	8	175	0.01	11.99	15.50	10.50

a Includes owned and hired farms, assuming one farmer to each.

APACHE COUNTY, located in the northeastern corner of Arizona, is second in size in the territory and sixth in the whole United States. The Navajo and Moqui Indian reservations cover the northern end of the county, and the White Mountain Indian reservation is located partly in the southern end, while between these are the railroad grants, leaving relatively little land open for settlement. The Little Colorado flows across the center of the county, and then turning northwesterly flows through narrow canyons to the Colorado. The principal towns are along the Little Colorado and its tributaries entering from the south, where there are areas of good agricultural lands. As a rule irrigation is required, although, especially at altitudes of 7,000 feet and upward, some dry farming is reported to be successful. The water supply is somewhat limited, scarcity being felt especially in June, July, and August.

A number of small irrigating ditches have been reported at Show Low, Taylor, Snowflake, and other points on Silver creek; also at Springerville, St. Johns (the county seat), Woodruff, St. Joseph, and other points on Little Colorado river. The principal crops irrigated were corn, oats, alfalfa, and beans. In the vicinity of Taylor are the ditches covering both sides of the valley and irrigating lands in the vicinity of Taylor and Snowflake. These ditches are from 3 to 4 miles long, and have cost in all about $25,000. Work was begun in 1877, and the ditches were practically completed within a few years. Water rights have cost from $12 to $15 per acre, and the annual assessment has been from 90 cents to nearly $5 per acre, the latter large amount owing to injuries by flood. It is stated that it is usual to give 3 good waterings to wheat and oats, 2 for a crop of corn, and 1 or 2 irrigations for each cutting of alfalfa.

At Springerville, south of St. Johns and on the headwaters of Little Colorado river, are several ditches on both sides of the stream. The principal ones were begun in 1872 and used in the following year. They are owned mainly by private parties, who share the expense. This is estimated to be annually about $1.25 per acre. At St. Johns the main ditch is known as the Gibbons or Mill ditch. It is about 4 miles long, 6 feet wide, and has cost probably $10,000. The principal crops irrigated are wheat, corn, barley, and oats. The St. Joseph ditch heads about 12 miles from Holbrook and covers land on the north side of Little Colorado river. It is about 7 miles long, 6 feet wide, and with the dam has cost about $45,000. This latter, it is stated, has been replaced 8 times within 14 years. The first cost of water right was about $7 per acre, but the annual assessments, the greater part of which have been for repairing the dam, have been from $2 to $5 per acre.

Attempts have been made to obtain flowing wells, and the board of supervisors of the county, in compliance with an act of legislature, has offered a reward of $2,000 to any person who should first obtain a flowing stream of water of not less than 17,500 gallons per day, such well, however, not to be upon military or railroad lands nor within 10 miles of any other flowing artesian well nor within a mile of any permanent flowing stream of water.

COCHISE COUNTY is in the southeastern corner of the territory bordering upon New Mexico and the republic of Mexico. In general altitude it ranges from 3,000 to 6,000 feet and upward. Agricultural lands are to be found in nearly all of the valleys or broad plains, the principal irrigated areas being on the western side of the county along San Pedro creek and its tributaries, mainly in the vicinity of Hereford, Fairbanks, Benson, and Tres Alamos. This stream furnishes the greater part of the water supply of the county, the other rivers and creeks being of such an intermittent character that irrigation is exceedingly difficult. Even in the case of the San Pedro there is far more land than the water will supply, and as a result litigation has arisen concerning the water rights. During periods of drought the entire amount of running water is diverted by the various dams across San Pedro creek, some water reappearing in the channel to be again taken out at points below.

Around the edge of Sulphur Spring valley, which occupies the center of the county, a small amount of irrigation has been practiced, mainly for the purpose of raising hay or for increasing the area of grazing lands. It is reported that in many localities wells reach water at from 10 to 40 feet, and it is probable that some of this can be brought to the surface with profit by means of pumping machinery. Deep wells have been drilled in the hope of obtaining artesian water, but so far as can be ascertained these have not been successful. Among the higher mountain valleys small crops have been raised without irrigation, but as a whole it may be said that this method of cultivation is essential throughout the county, and especially so for fruits. With an ample supply of water, orchards and vineyards are exceedingly profitable.

GILA COUNTY, the smallest in the territory, occupies a position largely within the drainage basin of the Salt river, on the south crossing the mountains and reaching to the Gila river. On account of its position it is comparatively well watered, but the valleys are narrow and there is little arable land. The White Mountain Indian reservation covers the greater portion of the county, leaving only a narrow strip of land on the western side. The tilled land is principally along the Salt river, between Pinal and Tonto creeks, or in their vicinity. Among the headwaters of Tonto creek and in the Tonto basin, at an elevation of from 6,000 to 7,000 feet, corn and potatoes are raised without irrigation if the land is carefully tilled. Other crops require the artificial application of water.

GRAHAM COUNTY lies to the southeast of Gila, between Apache and Cochise counties, filling in the eastern side of the territory. It is thus in or near the headwaters of the Gila river, and, like Gila county, is largely mountainous. The principal area of agricultural land is in the Pueblo valley, extending from a canyon above Solomonsville for about 30 miles to Fort Thomas, the principal settlements being, in order, Solomonsville, Safford, Central, and Pima. The Gila is the source of supply for the valley. A number of dams are placed across it at intervals of 2 miles or more. When the flow of the stream diminishes in May and June the dams of logs, brush, and stone are tightened so as to turn all the water into the canals. Below each dam, however, the water begins to rise in the bed of the stream, so that by the time the next dam is reached there is apparently as much water as before. If the summer rains fail the river may become entirely dry in July and August, loss of crops resulting.

At present the acreage under cultivation is not greatly in excess of the usual water supply, and the losses are not such as to call for immediate water conservation. In view of future extensions, it is already recognized that active steps must soon be taken. There appears to be no comprehensive system of water distribution, and the present needs point to a consolidation of the various small ditches into a few high-line canals, both to reduce the expenses and to effect a greater economy in the use of the water. The river, occupying a wide sandy bed, is unstable, and during freshets is liable to cut new channels, leaving the dams on dry land. Some cultivation by irrigation is successful in the valleys south of the river at the foot of the mountains, where small streams or springs issue. The greater portion of this water is lost for lack of facilities for holding the spring flow until later in the season.

As examples of the irrigating ditches brief descriptions may be given as follows: the Union irrigation canal heads about 1.5 miles northwest of Solomonsville. It is 13 miles long, 12 feet wide, and has cost $15,000. The Graham ditch heads about 2 miles east of Safford, taking water out on the north side of the river. It is 4 miles long, about 6 feet wide, and has cost over $2,000. The work was begun in 1879, and it has been enlarged since that time. It is owned by farmers, who divide the water and share the annual expenses, which are estimated to have been about $2 per acre. The principal crops irrigated are wheat, barley, oats, corn, beans, Irish and sweet potatoes, and garden vegetables. The Montezuma and neighboring ditches also cover land in the vicinity of Safford, water being diverted from the Gila by means of dams built of wood, stones, and brush. These dams are often washed out, increasing largely the annual expenditures. The ownership in most of the irrigation works is divided into shares, each entitling the owner to a certain proportion of the water. A water master, appointed by the irrigators, calls upon each when necessary to make repairs, or hires labor, which is paid for by a cash assessment.

In the vicinity of Pima are a number of ditches owned by asssociations of irrigators, who share the work and expense necessary to keep them in repair. The principal expense in these ditches is in rebuilding the diverting dams. The crops irrigated are alfalfa, barley, beans, and potatoes. Alfalfa is watered after each cutting, and the cereals receive 2 or 3 irrigations. Garden vegetables require irrigation every 8 or 10 days, orchards 5 or 6 wettings during the year, and vineyards 3. Difficulty has been experienced in obtaining sufficient water on account of the small size of some of these canals, although there is usually sufficient in the river. The owners are generally men of small means and are not able to construct or maintain the works in the most economical manner, and the water supply is not utilized as thoroughly as in the case of better equipped systems of supply.

MARICOPA COUNTY, in value and extent of irrigation, as well as in agricultural development, leads the others in the territory. It contains over one-half of the irrigated land and the greater number of the irrigating canals. The amount of land actually utilized in the census year was small in comparison with the area under these canals, and formed an almost insignificant part of the vast extent of arable land which with water could be rendered valuable. The results attained have shown that the lands of this county, especially those within the Salt river valley, when properly wet, can produce enormous crops, and when planted with trees and vines have the requisites for the successful cultivation of many of the most valuable fruits, rivaling in this respect favored portions of California. In some particulars the Salt river valley and the lands along the Gila are claimed to have advantages for fruit growing in that they are nearer the markets of the east, so that the green fruit is not only hauled a less distance, but also is saved a day's journey through the hot desert. It is asserted also that grapes and other fruits ripen earlier in the season and can be put on the market far in advance of the California products.

The principal irrigated areas are in the vicinity of Phenix, the territorial capital, and also near Mesa and Tempe, extending along both sides of Salt river from below the Verde and the Salt River Indian reservation westerly at intervals to and even below Gila Bend. The water supply is derived mainly from Salt river, large canals heading also on the Gila itself below the mouth of the first named stream. Taken as a whole, the water supply is large, but fluctuates greatly, having far less regularity than in the case of rivers farther to the north. Measurements of the amount flowing in the Verde and Salt have been made at various points by the United States Geological Survey, the most important of these being shown by the following tables:

VERDE RIVER, NEAR FORT McDOWELL, ARIZONA.

(Drainage area 6,000 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
August 14 to 31	480	154	207	12,730	0.04	0.03
September	340	140	192	11,424	0.03	0.03

SALT RIVER, 50 MILES ABOVE PHENIX, ARIZONA.

(Drainage area, 5,880 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1890.						
May 28 to 31	520	523	520	31,980	0.10	0.09
June	520	193	298	17,731	0.06	0.05
July	375	185	215	13,222	0.04	0.04
August	2,200	600	1,362	83,763	0.27	0.23

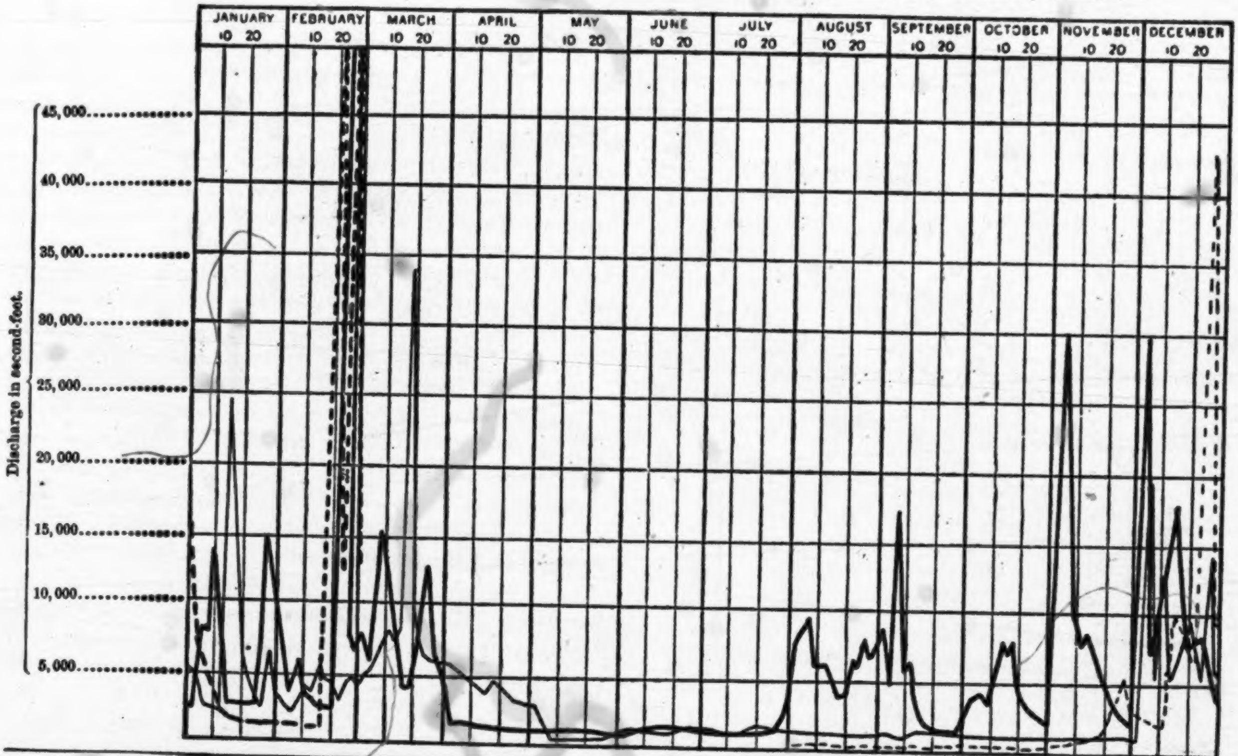
The longest series of observations have been carried on under the direction of Samuel A. Davidson at the headworks of the Arizona canal, of which he has been engineer. The results are shown by the table and diagram on the following page. On this diagram the discharge for 1888 is indicated by the lighter broken line, that for 1889 by the lighter continuous line, that for 1890 by the heavier continuous line, and for the following two months by the heavier broken line.

SALT RIVER AT ARIZONA DAM, ARIZONA. [a]

(Drainage area, 12,260 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1888.						
August	....	....	350	21,525	0.03	0.03
September	....	....	350	20,825	0.03	0.03
October	350	300	331	20,356	0.03	0.03
November	5,760	425	842	50,099	0.08	0.07
December	43,489	1,665	6,698	411,927	0.63	0.55
1889.						
January	24,953	1,665	5,947	365,740	0.56	0.58
February	3,940	1,534	2,605	144,577	0.22	0.22
March	33,794	3,563	8,745	537,817	0.82	0.71
April	5,559	2,496	3,975	236,512	0.36	0.32
May	1,784	622	1,039	63,898	0.10	0.08
June	615	356	470	27,965	0.04	0.04
July	1,311	334	495	30,522	0.05	0.04
August	755	389	417	25,645	0.04	0.03
September	1,172	389	521	31,000	0.05	0.04
October	704	319	440	27,060	0.04	0.04
November	629	532	576	34,272	0.05	0.05
December	25,371	557	5,686	349,639	0.53	0.46
Per annum	33,794	319	2,576	1,874,697	2.86	0.21
1890.						
January	15,750	1,376	4,982	306,333	0.47	0.40
February	143,288	1,045	10,097	560,383	0.86	0.83
March	17,228	2,566	6,421	394,891	0.60	0.52
April	2,077	1,369	1,840	109,480	0.17	0.15
May	1,369	630	914	56,211	0.09	0.08
June	672	397	511	30,404	0.05	0.04
July	872	397	524	32,226	0.05	0.04
August	7,734	1,114	3,885	238,927	0.37	0.32
September	3,685	725	2,339	139,170	0.21	0.19
October	7,465	753	2,768	160,232	0.25	0.22
November	30,507	766	4,717	280,661	0.43	0.38
December	30,366	1,110	6,259	384,928	0.59	0.51
Per annum	143,288	397	3,771	2,693,906	4.14	0.31

DIAGRAM OF DAILY DISCHARGE OF SALT RIVER AT ARIZONA DAM, MARICOPA COUNTY, ARIZONA.



---

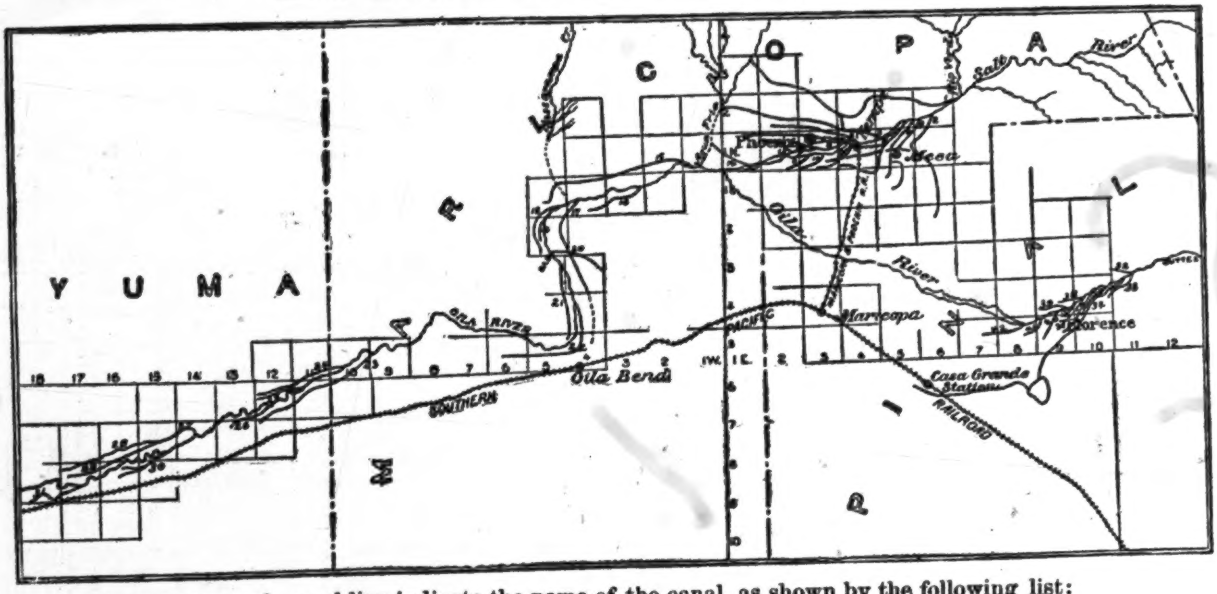
[a] Measurements of Salt river at Arizona dam were abruptly broken by the great flood of February, 1891. This flood, which reached an estimated maximum of 300,000 second-feet, seriously injured the dam and headworks of the Arizona canal and carried away nearly all the dams, bridges, and other obstructions in or near the river banks. The flow for two months in 1891 (estimated for February) was:

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1891.						
January	17,127	1,060	3,416	210,084	0.32	0.28
February	300,000	825	39,201	2,175,055	3.32	3.10

Comparing the flow of this river with that of many of the other rivers discussed in this report, the most notable difference is the low water during April, May, and June, months when the streams of the rest of the country reached their highest. The suddenness with which these floods come and go in the Gila and its tributaries is in striking contrast to the slow rise and fall of the snow fed rivers upon which most of the irrigation in the United States depends.

The location of most of the more important canals of this and adjoining counties is shown on the accompanying map. Taking these along the Salt river in order downstream, the highest on the north side of the river is the Arizona, and below this the Grand, Maricopa, and Salt river valley, these 4 canals forming one system and covering lands north of and around Phenix. Farther downstream, below Phenix, are the Griffin, Farmers, St. John, and other ditches. On the south side of the river, and heading a short distance below the Arizona, is the Highland, whose general direction is nearly south, covering lands east of Mesa city. Below this come the Mesa, Utah, and Tempe canals, the latter irrigating lands immediately adjacent to the town of Tempe. Below this in order are the San Francisco, French, and Broadway. Below the junction of the Salt and Gila are a number of important canals projected and partially constructed. The first of these is the Buckeye, on the north side of the river, heading near the junction of the channel of the Agua Fria. About 25 miles west of this stream the channel of the Hassayampa enters from the north; the Gila swings to the south for about 20 miles and then again to the west, forming what is known as Gila Bend. Near the junction of the Hassayampa, on the right bank of the river, are the headworks of the Gila river and the Monarch canals, and about 8 miles below is the head of the Enterprise canal. On the left bank of the Gila river, halfway between Agua Fria and Hassayampa creeks, is the head of Rumberg's canal, and below this the proposed St. Louis canal. About 8 miles below Hassayampa is the dam of the Gila Bend Reservoir and Irrigation Company, one of the largest projects in the territory, the canal for diverting the water coming out toward the east and south. Below this is the Lower Gila Bend or Palmer canal.

MAP OF IRRIGATION CANALS IN THE GILA VALLEY, ARIZONA.



The figures near each canal line indicate the name of the canal, as shown by the following list:

1. Arizona.
2. Highland.
3. Mesa.
4. Utah.
5. Tempe.
6. Grand.
7. San Francisco.
8. Maricopa.
9. Salt River Valley.
10. French.
11. Broadway.
12. Griffin.
13. Farmers.
14. St. John.
15. Buckeye.
16. Rumbery's.
17. St. Louis.
18. Gila River.
19. Monarch.
20. Gila Bend Reservation and Irrigation Company.
21. Enterprise.
22. Lower Gila Bend.
23. South Gila.
24. Farmers.
25. Purdy.
26. Contreres.
27. Mohawk.
28. North Branch of Mohawk.
29. South Branch of Mohawk.
30. South Mohawk.
31. Antelope.

The Arizona canal diverts water from Salt river by means of a weir or dam over 900 feet long, located about a mile below the mouth of the Verde. The canal follows the bank of the river for a short distance and then gradually turns toward the northwest. Near the head the bottom width is 36 feet, narrowing to 30, and the estimated capacity nearly 1,000 second-feet, the grade being 2 feet per mile. For the first 3.5 miles the canal was excavated in rock or gravel, the expense of construction being heavy. Work was begun in 1883 and water was first used in 1887. The total length of the main ditch was 41 miles, and the cost, including the dam, about $600,000. After leaving the

Indian reservation lateral ditches run south toward Phenix covering every section. Water rights have been sold at the rate of $12.50 per acre, the annual assessment being $1.25 per acre.

It has been found that 1 second-foot of water was sufficient to produce crops of all kinds on 80 acres of land. For economical use a stream flowing at the rate of 2 second-feet is to be preferred, and with this quantity of water 10 acres of grain or alfalfa or 20 acres of fruit trees can be irrigated in 24 hours. The corporation owning this canal has purchased also the Grand, Maricopa, and Salt river canals, covering land under the Arizona, and which are now used largely as distributaries. The Grand canal is 27 miles in length and has an estimated capacity of 200 second-feet. The Maricopa is about 26 miles long, from 16 to 18 feet wide on bottom, and has a capacity of 140 second-feet. The Salt river canal, heading on the river at the same point as the Maricopa, these together being known as the Consolidated, has a width of 22 feet, a length of 26 miles, and capacity of about 160 second-feet. These are connected with the Arizona canal by means of a crosscut having a capacity of 375 second-feet.

The Mesa canal, heading on the south side of the river about 5 miles below the Arizona dam, takes water out in the vicinity of the town of Mesa. The total length of the main ditch is approximately 10 miles, the average width 15 feet, and the cost is placed at $75,000. Work was begun in 1878, and the canal was used in the following year. The diversion dam is of brush and stone and has been replaced after several floods. The works are owned by a corporation consisting of farmers, the property being held in 400 shares, each of these entitling the holder to a proportional part of the water. The cost of the water right was originally about $15 per acre, and the annual tax is about $1 per acre. It is estimated that water was used under this canal at the rate of 1 second-foot to 80 acres, although the theoretical water duty is far higher. This, as well as the adjacent canals, is being rapidly extended, bringing more land into use for fruit and alfalfa.

The Tempe canal is 24 miles long, about 25 feet wide, and has cost over $120,000. Work was begun in 1870 and water used in the following year. It is owned by an association, each share entitling the holder to 100 inches or about 2.5 second-feet, this amount being considered sufficient for 160 acres. The first cost of the water right was estimated to have been $10 per acre, and the annual assessment has varied from 20 cents to 30 cents per acre.

The Buckeye canal takes water from the Gila about 4 miles below the junction of the Salt, carrying it out on the north side. The river at this point as a rule flows the year round, but is stated to have been dry in extraordinary seasons. The total length of the main ditch is 28 miles, the average width 12 feet, and the cost was estimated to be $120,000. Work was begun in 1885 and water used in 1888. The ownership is divided into shares, each of these representing 80 miner's inches. The annual assessment is $1 per miner's inch. It is usually calculated that 80 inches will furnish sufficient water for 160 acres.

The dam of the Gila Bend Reservoir and Irrigation Company is located about 45 miles southwesterly from Phenix and 22 miles north of Gila Bend station. The canal from this is being constructed along the left bank of the river and southerly toward Gila Bend station, it being proposed to continue this along and across the Southern Pacific railway, thus covering an immense area of fertile land. The Lower Gila Bend canal heads about 10 miles below the dam of the canal just mentioned and covers a narrow strip of land on the same side of the river. The total length of the main ditch is 15 miles, the average width 11 feet, and the cost was $25,000. The canal was begun in 1884 and first used in 1885. Water is diverted by means of a dam of brush and stone replaced in whole or part each year. The works are owned by farmers and held in 36 shares, each entitling the holder to a proportional part of the water.

MOHAVE COUNTY occupies the extreme northwestern corner of the territory, adjoining Utah and Nevada. An exceedingly small amount of cultivation was reported, the total area in cereals being only 10 acres of wheat and the total production 25 bushels. Cattle raising was about the only industry of importance. During and before the census year attempts at farming were made along Sandy creek, but the floods of 1889 are reported to have washed away more than half the farming land, and apparently it was only a question of a short time before the rest would be destroyed. Taking the county as a whole there is plenty of agricultural land, but the difficulty of obtaining water stands in the way of development. Hay and grain for the mining camps have been brought from California, and butter, eggs, bacon, and similar supplies from Kansas. The Colorado river forms a portion of the western boundary of this county and carries at all times a large amount of water. Little, if any, of this can be utilized on account of the depth to which the river has cut below the arable lands. The difficulties of taking out the water of this river appear to be almost insurmountable, although it is possible that by the expenditure of large sums lands in the southeastern part of California may be reclaimed. A few measurements of the actual quantity of water in the Colorado were made in 1875 and 1876, showing that the discharges at the times of observation varied from 8,000 to 18,000 second-feet, and probably reached during flood 50,000 second-feet.

PIMA COUNTY is situated along the central part of the extreme southern border of the territory adjoining Mexico. Agriculture is confined to the eastern end, near Cochise county, where the elevations range from 2,500 feet upward. The Santa Cruz and Sonoita and their tributaries are the only sources of water supply, with the exception of a few springs among the foothills of the mountains. The amount of water is small in comparison to the acreage already under cultivation, and crops are frequently lost during the dry season. A number of ditches are taken out in succession along the Santa Cruz from Calabasas down to Tucson. In the vicinity of Crittenden is the Pennsylvania Ranch ditch, 7 miles long and 3 feet wide, receiving its water mainly from the springs of Sonoita creek, corn, alfalfa, and barley being irrigated. At the junction of the Sonoita with the Santa Cruz, about 8 miles north of Nogales, is a ditch 4 miles long and 3 feet wide, which is stated to have cost $800. Among the ditches farther down on the Santa Cruz is one on the west side, taking water out in the vicinity of San Xavier, 4 miles in length and from 2 to 3 feet in width. The annual cost of water is estimated to be 50 cents per acre. Farther north, in the vicinity of Tucson, is the Goodwin ditch, covering land on the east side of the river. It is 3.5 miles long, about 3 feet wide, and has cost $2,500. Water is obtained from an open cut, penetrating the bed of the river to a depth of about 6 feet. The Davidson canal takes water from Rillito creek, a stream usually dry on the surface for about one-half of the year, the sandy channel, however, being saturated with water. Work was begun about 1887, and the cost before completion had already reached $25,000. It is proposed to draw the water from a depth of 14 feet beneath the surface by means of a drain or aqueduct 4 feet 6 inches wide and 3 feet 6 inches high at the sides. This is to be so protected that floods will pass over it without injuring it. The object sought is to secure a permanent supply of water in order to guarantee the success of orchards and vineyards. The ordinary surface ditches are not always sure of receiving water, and while annual crops can be raised, vineyards and orchards have been lost or injured by total failure of supply.

PINAL COUNTY includes a portion of the Gila valley above the mouth of Salt river, and in some respects possesses advantages for irrigation as great as those had by the lands in the vicinity of Phenix. The agricultural land now utilized is mainly in the vicinity of Florence, along the river below the point where it cuts through a transverse range of hills or mountains. Above this point, along and below the mouth of San Pedro creek, is a second district in which irrigation is practiced, water being obtained from the creek at various points above the town of Dudleyville and also from the river in the valley below that place. The cereal most cultivated is barley, next in importance to this is wheat. Large acreages have been devoted to alfalfa, and each year the area in orchards and vineyards steadily increases.

The quantity of water available has been measured for one year only. The gauging station on the Gila was located about 15 miles above the town of Florence, at the Buttes, being thus above the head of canals and where, owing to the character of the channel, the best results could be obtained. The following table gives the computed discharge. This was a year of prevailing low water, and there were few of the sharp, sudden floods so characteristic of the stream. One of these occurred in August, 1890, just previous to the abandonment of the station. (*a*)

GILA RIVER AT BUTTES, ARIZONA.

(Drainage area 13,750 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
August 26 to 31	124	110	115	7,072	0.009	0.008
September	210	90	128	7.616	0.010	0.009
October	210	140	157	9,655	0.013	0.014
November	250	156	212	12,614	0.017	0.015
December	890	124	275	16,912	0.023	0.020
1890.						
January	2,100	310	680	41,820	0.057	0.049
February	1,514	405	578	32,079	0.044	0.042
March	710	300	387	23,805	0.032	0.028
April	333	158	238	14,161	0.019	0.017
May	150	35	87	5,350	0.007	0.006
June	35	27	28	1,666	0.002	0.002
July	3,112	11	130	7,995	0.011	0.009
August	6,330	1,115	3,137	192,925	0.262	0.228

San Pedro creek was gauged for a time during the summer of 1890, and discharges were computed, as shown in the table on the following page. As previously stated, the low water prevailed during this year and little irrigation was possible from the waters of this stream. Above the point of measurement there were at the time a number of ditches, mainly of from 1 to 2 miles in length, taking out water, so that, omitting the small floods which occasionally occurred and lasted for a few hours, the quantity measured may be considered perhaps as representing the seepage water. Although this stream has a large catchment area, the run-off, like that from adjacent basins, is exceedingly small.

---

[a] The greatest flood known in years happened in February, 1891, the total amount of which, however, has not been approximated.

SAN PEDRO, AT DUDLEYVILLE, PINAL COUNTY, ARIZONA.

(Drainage area 2,819 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.		MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.		Maximum.	Minimum.	Mean.		Depth in inches.	Second feet per square mile.
1890.							1890.						
April 9 to 30	21	5	14	623	0.005	0.005	July	225	1	13	800	0.005	0.005
May	9	5	6	369	0.002	0.002	August	507	102	295	18,140	0.121	0.105
June	5	1	3	179	0.001	0.001							

The necessity of water storage is perhaps as well appreciated in this county as in any part of the territory. During the census year there was unprecedented scarcity of water, due not only to a diminution of river flow, but to an increased diversion on the part of all the ditches, most of which had been gradually enlarged from time to time. Surveys have already demonstrated the feasibility of holding flood waters at various points, particularly in the valley above the Buttes, 15 miles from Florence.

The principal ditches on the north side of the Gila river are Moore, McLellan, Stiles, and Swiss; on the south side, Brash, the Florence canal, Montezuma, Holland, Alamo Amarilla, Brady, Adamsville, White, and Walker. Nearly all of these are owned by individuals, the principal exceptions being the Florence canal and the Montezuma and Alamo Amarilla ditches. The McLellan ditch heads about 10 miles above Florence, covering lands on the north side of the river. It is over 5 miles in length, 4 feet in width, and the cost was probably $5,000. Work was begun in 1871, and the ditch was finished in 1872. Water is diverted by means of a dam composed of triangular cribs loaded down with rock and covered with brush and stone. There is generally an ample supply, but need of water is sometimes felt in June, July, and August. The first crop raised consists mainly of barley, wheat, beans, and early corn, and the second crop of beans, corn, sweet potatoes, pumpkins, watermelons, and sugar cane. Water is usually turned into the ditch in October and November, and used until the end of the spring floods. It is stated that the water in this part of the river has been diminishing for 6 years, owing probably to diversions from the San Pedro and from the Gila near Solomonsville and other towns. The Swiss ditch takes water from the north side of Gila river in the vicinity of Florence. It is about 4 miles long, 10 feet wide, and probably cost about $2,500. It was begun in 1872 and used in the same year. The water supply at this point is often insufficient, generally on account of the fact that it is diverted at points above by other canals having prior rights. The need is felt most in May, June, and July, and sometimes in August. The principal crops irrigated are alfalfa and grain, the latter being cut sometimes for hay, and besides these, garden vegetables and fruit trees are watered regularly.

The Florence canal heads about 12 miles above the town of that name and, coming out of the south side of the river, it is continued beyond the town in a southwesterly and southerly course nearly to the Southern Pacific railroad. The total length is reported to be upward of 50 miles, the average width 20 feet, and the cost was placed at $400,000. Work was begun in 1886, and water was first used in 1888. The diverting dam is of brush and is replaced each year. The canal is owned by a corporation which sells water rights at the rate of $8 per acre above the reservoir and $12.50 per acre below the reservoir. The annual assessment is $1.25 per acre. A reservoir has been constructed about 25 miles from the head of the canal, having an area of 1,800 acres and an estimated storage capacity of 6,000,000,000 gallons. Besides this it is proposed to construct another reservoir at the Buttes, about 3 miles above the head gates.

YAVAPAI COUNTY, the largest in the United States (*a*), comprises about one-fourth the area of Arizona. The county contains an exceedingly small proportion of irrigable land, since it includes that part of Arizona adjoining Utah which contains the greater portion of the grand canyons of the Colorado. These stupendous gorges cut the great plateau to the depth of from 3,000 to 6,000 feet. The minor lateral canyons, in which flow the tributaries of the Colorado, are also cut to a great depth, which decreases toward their head waters. Thus the water of the northern part of the territory, though large in amount, is wholly useless, lying as it does hundreds and thousands of feet below the level of the arable lands. It is only toward the southern portion of the county, where the great plateau begins to break off and the valleys are less deep and narrow, that agriculture has been seriously attempted. Along the line of the Atlantic and Pacific railroad, which crosses the county from east to west, at an elevation of from 5,000 to 7,000 feet, some crops, especially for forage, are raised without irrigation. For example, at Flagstaff, at an elevation of about 7,000 feet, corn, potatoes, and vegetables, as well as a little wheat, oats, and barley are thus cultivated, the cereals being generally cut for forage purposes. The same is true of Prescott, although near that place irrigation has been employed wherever practicable. On the head waters of the Agua Fria, at an elevation of about 4,500 feet, there is also a little dry farming.

---

[a] Since 1890 Yavapai county has been divided, the northern portion, with Flagstaff as the county seat, being set off under the name of Coconino.

The principal bodies of irrigated lands are along the Verde river and its tributaries, Oak, Clear, Beaver, and other creeks, both above and below Camp Verde, where a number of small ditches have been built by farm owners. On Walnut creek, which heads west of Prescott and flows northerly into Big Chino valley, and on Granite creek to the east, all the available waters are utilized and the irrigators are discussing the feasibility of water storage. On the head waters of Hassayampa river, a short distance southerly from Prescott, two dams have been built, mainly for the purpose of supplying water for hydraulic mining. The upper of these, that at Oro Fino, was built about 1885, the height being about 20 feet. It is located near the mouth of the upper canyon, below which is the farming land of Walnut Grove valley. This is about 7 miles in length and from 1 to 3 miles in width. At the foot of this valley the Walnut Grove Water Storage Company built the dam the destruction of which by a great flood in February, 1890, caused large loss of life and property. This dam was 420 feet long on top, 138 feet wide at bottom, 15 feet wide at top, and 110 feet in greatest height. It was planned to use the water both for placer mining and purposes of stock raising on the plains of the valleys below.

YUMA COUNTY, occupying the southwestern corner of the territory, comprises lands having the lowest altitude and the hottest climate of Arizona. In these respects it is surpassed by the desert regions of San Bernardino and San Diego counties, California, portions of which are far below sea level. This area possesses the advantage of having a fair water supply from the Gila, which flows westerly through it into the Colorado, which forms the boundary between Arizona and California. Along the Gila are several places where water can be brought out by means of canals, and the lands thus irrigated are capable of producing semitropical fruits. The Colorado itself, as previously stated, probably can not be used to any great extent for irrigation in this territory, owing to the almost insurmountable difficulties of diverting water. Small bodies of land are being brought under irrigation by means of pumps, raising water to lands upon or above the flood plains. This method of obtaining the water supply, although expensive, can probably be made profitable, owing to the value of the fruits produced.

Along the Gila the principal canals projected or constructed are, on the north side, the Farmers, Purdy, and Mohawk, and on the south side the South Gila, Contreres, South Mohawk or Saunders, and Antelope, the relative location of these being shown on the map.[a] The Saunders is probably the oldest canal along this part of the river, having been used first about 1868, but not completed until 1884. It is 10 miles long, 8 feet wide, and has cost $25,000. It is owned by a company which uses the water upon its own land. The annual cost for water is about 50 cents per acre. The principal crops are alfalfa and barley, for the former of which almost constant irrigation is considered necessary.

---

[a] Some of these schemes for diverting water were abandoned or modified, owing to the disastrous flood of 1891, which carried away much of the preliminary work along the banks.

CALIFORNIA.

Total population (average per square mile, 7.75)		1,208,130
Number of owners of farms (4.38 per cent of population)		52,894
Number of irrigators (25.96 per cent of farm owners, 1.14 per cent of population)		13,732
Area of state, land surface (155,980 square miles)	acres	99,827,200
Area irrigated in census year	do	1,004,233
Area of all farms, 57.04 per cent improved	do	21,427,293
Cereals raised in census year, including 664 acres in buckwheat and 27.413 acres in rye	do	3,812,751
Barley, average production, 21.51 bushels per acre	do	815,995
Corn, average production, 33.87 bushels per acre	do	70,303
Oats, average production, 25.41 bushels per acre	do	57,569
Wheat, average production, 14.39 bushels per acre	do	2,840,807
Alfalfa	do	245,915
Total value of all farms, including land, fences, and buildings		$697,116,630
Estimated total value of the farms irrigated in whole or in part		$150,[illegible]5,000
Estimated value of all farm productions (sold, consumed, or on hand) for 1889		$87,033,290
Estimated value of productions, as above, from farms irrigated in whole or in part		$19,080,000
Average size of irrigated farms	acres	73
Average size of irrigated farms of 160 acres and upward	do	547
Per cent of acreage of irrigated farms of 160 acres and upward to total acreage irrigated		61.88
Average size of irrigated farms under 160 acres	acres	30
Average first cost of water right per acre		$12.95
Average annual cost of water per acre		$1.60
Average first cost per acre of preparation for cultivation		$17.48
Average value of irrigated land, including buildings, etc., in June, 1890, per acre		$150.00
Average annual value of products per acre, in 1889		$19.00

COMPARISONS WITH OTHER STATES.

Comparing California with the other 10 states and territories which go to make up the arid region as previously defined, it is seen that this state in area irrigated, number of irrigators, and average value of products per acre during the census year stood at the head, Colorado coming second in point of area, and Utah second in number of irrigators. In average size of irrigated area, 73 acres, California was number 5. When the area irrigated is considered in comparison with the size of the state, California stands second, since Colorado had 1.34 per cent of its entire land surface irrigated, and California 1.01 per cent. Taking the total number of farms in the state and placing against this the number irrigated, the relative importance of irrigation seems to fall in the scale; for California with only 25.96 per cent of all farms irrigated comes number 10 in the list, but this is somewhat compensated for by the large size of the farms irrigated, 17.86 per cent of land owned by irrigators being watered, the state standing seventh in this respect.

In average value on June 1, 1890, of farm land irrigated, $150 per acre, California leads the list, Utah coming second, with $84.25 per acre. This figure exhibits perhaps better than any other the extraordinary values of land in California arising from its utilization for orchards and vineyards. The value of these ranges from $300 to $500 and upward per acre, thus greatly raising the average value of irrigated land, which of course also includes great areas devoted to the raising of hay crops. The same fact is exhibited, though perhaps not as clearly, in the high average value of products per acre in 1889 and in the large average first cost of water rights, $12.95 per acre, and average value of these in 1890, $39.28 per acre, a high cost and value being justified by the enormous profits resulting from successful fruit culture. In short, it may be said that the conditions in California, although by no means perfect, have produced such results that they have served to stimulate development in all parts of western United States. Much is still to be accomplished by the subdivision of the great irrigated holdings, this state standing first in the aggregate area and average size of irrigated holdings of over 160 acres in area. These, although embracing 61.88 per cent of the total area irrigated, are not of as great relative importance as in Nevada and Wyoming, where the large farms are devoted mainly to the forage crops.

GENERAL DESCRIPTION.

California stands at the head of the states and territories not only in acreage of land irrigated and in value of the products, but in many other features it is unique and easily leads in its developments along this line of agricultural prosperity. The wonderful advantages of the state due to its peculiar topography and the resulting climatic conditions and water supply render it difficult to make general conclusions which can be applied with safety to the arid regions farther to the east. It is often the case that persons knowing of the results obtained in California have argued that benefits as far reaching must necessarily follow irrigation everywhere, and have been disappointed by not taking full cognizance of the many almost unparalleled features of this great sea coast state.

California as a whole can not be said to be arid; in fact the greater part of its broad valley lands possess a mean annual rainfall sufficient for maturing the small grains, but the necessity for irrigation lies mainly in the fact that the greater part of the rainfall occurs during winter and early spring and that for months during summer and autumn hardly a drop falls. This fact is brought out most clearly by the diagrams shown in preceding figures and by a subsequent table. In the really arid portions of the state, namely, those east of the Sierra Nevadas, irrigation has made relatively little progress, but its greatest development, excepting perhaps in Kern and Tulare counties, is to be found where wheat growing has been carried on successfully for years without the artificial application of water. The one factor which forces irrigation into such prominence in California is its vital importance to fruit growing in many sections. Were it not for this the subject of irrigation as adding immensely to the value of the lands of the state would receive comparatively little attention, for, next to the orchards and vineyards, the crop which depends most upon irrigation is alfalfa, ranking when compared with fruits far down in the scale of value. Taking away the fruit and alfalfa, irrigation would become of little moment, as the ordinary field crops are probably raised on the whole as profitably without as with this means of supplying moisture.

The most striking feature of the topography of California is the great valley between the Coast and Sierra Nevada ranges, opening near its center by a break in the first named mountains. The Sacramento river coming from the north meets here the San Joaquin from the south, and together their waters enter in succession a number of inland bays to mingle with those of the ocean. The Sierra Nevadas on the east, as a whole, dip gently toward this interior valley; the lower portions of the mountains being partially buried beneath its sediments, while they present abrupt faces to the country farther to the east, furnishing a small catchment area for the streams which escape in that direction. South of the great valley of California, and at some distance below its southern end, are chains of mountains near the coast, some of which, the San Bernardino in particular, rise to extraordinary heights above their bases. They inclose or bound valleys near the coast, and by the steepness of their slopes in part protect these valleys and aid in furnishing an unusually large supply of running water. In the same way in the northern part of the state are mountain masses of irregular outline which also serve, though to a less degree, in making valuable the lands around their feet.

IMPORTANCE OF IRRIGATION.

Irrigation is dependent upon the great topographical features above mentioned, since these have a determining effect upon the quantity and distribution of the moisture. There is no county in the state in which crops of some kind have not been raised, in some localities at least, without irrigation, and on the other hand, there are many counties, notably those along the northern coast, in which the artifical application of water is not employed except in rare instances. Thus, in discussing the importance and development of this method of agriculture it is necessary at all times to bear in mind the topography of each region as well as the resulting precipitation and water supply. Grouping the counties of the state as regards the necessity and advantages of irrigation, those in the southern end, forming what is popularly known as southern California, come first. Here, as a whole, the returns arising from the introduction of irrigation have been largest and the aggregate investment in irrigation works as regards the quantity of water handled has been the greatest, the systems for water storage and distribution being far in advance of those of any other part of the United States.

Next to the counties of southern California in the order of importance of irrigation come those in the southern or upper end of the San Joaquin valley, where the artificial application of water is essential in bringing about a higher state of development of agriculture. In these counties the production of the cereals and the raising of cattle and sheep were more or less successfully carried on before the construction of irrigating canals, so that in one sense this great valley was settled in a general way before irrigation was practiced to any considerable extent, but in order to support a dense population and to bring about a corresponding increase in value of lands great systems of water distribution were constructed, these being among the largest in the state and in the whole United States. The locality standing third as regards necessity of irrigation comprises counties in the Sacramento valley, where agriculture flourished and land values were comparatively high before the present ditch systems were built or used for agricultural purposes. Here mining and stock raising have always been of first importance, and it is only within the last decade that fruit growing has forced its way toward the front. The use of water in the Sacramento valley is mainly confined to the foothill region, where, at elevations above that of the central valley, orchards and vineyards flourish and yield wonderful results. Water is obtained to a large extent from the flumes and ditches constructed for working the placers and other deposits in which the hill country abounds. On the passage of the law relative to hydraulic workings many of these ditches fell into disuse and would have become entirely abandoned had not the discovery been made that the climate and soil of adjacent localities were singularly favorable for the production of fruit. These old mining ditches have therefore been extended and others constructed to meet the constantly increasing needs.

The northern counties of California and those lying along the eastern front of the Sierra Nevadas rank fourth as regards the importance of irrigation. Artificial watering of the fields is practiced mainly for the purpose of raising forage crops on the broad meadow lands which occur in many of the basins within these counties. On account of the general lack of transportation facilities fruit growing has not reached a high degree of importance, and the irrigation works in use are of the simplest possible description. The coast and bay counties, as before mentioned, have little, if any, need for irrigation, and where this is practiced it is generally in a small way, a few acres of trees or alfalfa being watered. The annual rainfall is sufficient for all needs, but there is a time in summer during which water may be of benefit if applied judiciously. In many of the northern and coast counties irrigation is practiced not only to furnish the requisite moisture, but also to prevent the ravages of various small animals, and in particular to protect the fields of alfalfa. In many localities the so-called gophers are particularly destructive, breeding with incredible rapidity and ravaging the alfalfa fields, which they honeycomb with their burrows. A thorough flooding of the whole area must, of course, completely fill their holes, and as a result these little pests are drowned.

RAINFALL AND WATER SUPPLY.

The great fluctuation in rainfall month by month has been illustrated by diagrams in the preceding pages, where are shown the relatively heavy rainfall in the early part of the year and the almost complete lack of precipitation during August, September, and October. This same characteristic prevails throughout the state, whether the mean annual rainfall be large or small, and has perhaps more influence as regards the importance of irrigation even than has the total amount of the annual precipitation. (*a*) Though the annual rainfall may be as large as that in some of the eastern states, yet it is necessary to guard against the evil effects to orchards and vineyards of the long severe drought of summer and autumn by building expensive canal systems and providing other means of distributing the water.

The water supply of the state is far better than that of any of the arid states and territories to the east. The Sierra Nevadas and other ranges force the moisture laden winds coming from the ocean to drop a large part of this moisture in the form of snow or rain, giving rise to almost innumerable streams. These flow down to the valley lands, bringing sediment of considerable value to plant life. Many of the smaller streams at least sink into the ground at points near the edges of the valleys, and thus to obtain the largest and best use of their waters they must be diverted before they leave the canyons in the foothills. The total quantity of water in many of these streams has been measured from time to time and computations have been made of the discharges month by month for several years in succession, this work being carried on mainly under the direction of the state engineering department. The results of this work are given in the county descriptions.

---

a The subject is more fully treated in Irrigation and Water Storage in the Arid Regions, by General A. W. Greely, Chief Signal Officer, United States army. Fifty-first Congress, second session, House of Representatives, Executive Document No. 287, February 28, 1891.

MEAN MONTHLY AND ANNUAL RAINFALL AT STATIONS IN CALIFORNIA.

[T. indicates a trace of rain, less than 0.01 inch.]

LOCALITIES.	Altitude.	Length of record.		January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
	Feet.	*Yrs.*	*Mos.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Alameda county:																
Livermore	485	*a*20	4	2.63	2.34	2.04	1.30	0.45	0.15	0.02	T.	0.14	0.71	1.64	2.98	14.40
Niles	87	*a*19	5	3.16	2.90	2.43	1.53	0.60	0.23	....	T.	0.12	0.71	2.28	3.66	17.62
Amador county:																
Sutter Creek	....	15	4	6.22	4.34	4.68	4.24	1.33	0.37	0.02	0.02	0.28	1.94	3.64	4.70	31.78
Butte county:																
Cherokee	....	12	4	13.35	9.96	11.70	3.78	2.06	0.73	0.30	0.24	0.54	4.08	7.80	5.77	60.31
Chico	193	*a*19	5	3.86	3.29	2.73	1.02	9.84	0.37	0.03	0.01	0.27	1.45	2.40	4.04	20.91
Calaveras county:																
Valley Springs	....	*a*2	10	4.17	1.06	3.82	1.83	1.79	....	....	....	0.16	1.41	2.50	5.11	22.45
Colusa county:																
Orland	234	11	11	2.12	1.85	2.37	1.52	0.77	0.37	....	....	0.18	1.20	2.12	3.55	16.05
Princeton	57	*a*12	4	2.98	2.21	1.67	1.54	0.55	0.49	0.10	0.12	0.24	1.10	1.64	2.60	15.24
Contra Costa county:																
Brentwood	80	*a*10	5	2.32	1.53	2.01	1.36	0.36	0.20	....	....	0.14	0.75	1.66	2.69	13.02
Del Norte county:																
Fort Ter Wah	150	*a*2	3	9.97	8.78	8.50	6.07	3.63	0.17	0.66	0.71	3.81	5.64	12.71	11.52	72.17
Eldorado county:																
Georgetown	2,433	*a*17	8	11.08	7.81	9.15	6.44	2.51	0.75	0.05	T.	0.43	3.47	5.56	10.42	57.67
Shingle Springs	1,427	*a*21	11	7.72	4.09	5.34	3.20	1.40	0.18	0.20	....	0.23	1.11	4.26	7.53	35.26
Fresno county:																
Firebaugh	150	13	7	1.78	1.14	1.34	0.98	0.16	0.18	....	....	0.07	0.31	1.52	1.28	8.76
Fresno	328	*a*13	6	1.32	1.17	1.32	1.34	0.36	0.10	T.	T.	0.10	0.57	1.24	1.50	9.02
Humboldt county:																
Fort Gaston	397	*a*28	1	10.84	7.97	7.55	4.69	1.87	0.82	0.14	0.11	0.85	2.90	7.33	10.37	55.46
Humboldt Light	8	*a*12	7	5.79	5.02	5.30	2.82	1.24	0.47	0.16	0.06	0.55	1.68	3.79	7.14	34.61
Inyo county:																
Fort Independence	4,598	*a*12	4	1.22	0.56	0.52	0.21	0.27	0.04	0.11	0.22	0.07	0.32	0.21	2.26	6.01
Kern county:																
Mojave	2,751	13	0	0.73	1.14	0.74	0.23	0.01	0.08	0.06	0.08	0.04	0.24	0.31	1.50	5.25
Sumner	422	*a*13	10	0.94	0.85	0.58	0.89	0.30	0.09	....	....	....	1.50	3.37	3.98	12.50
Tehachapi	3,964	*a*13	5	1.40	3.17	1.66	1.62	0.40	0.11	0.01	0.15	0.02	0.53	0.62	1.79	11.68
Lake county:																
Kono Tayee	1,350	*a*10	9	5.13	3.78	4.17	1.09	0.52	0.52	....	0.01	0.17	1.03	3.19	1.71	21.32
Lassen county:																
Susanville	4,195	*a*3	0	4.34	2.95	4.04	1.28	3.02	0.97	0.31	0.15	....	1.50	3.37	3.98	25.91
Los Angeles county:																
Los Angeles	330	*a*18	5	4.08	3.74	2.27	1.29	0.31	0.09	0.02	0.10	0.04	0.82	1.71	3.84	18.31
San Fernando	1,066	*a*12	2	2.11	3.16	3.01	1.75	0.36	0.17	0.02	....	0.03	0.80	1.54	3.48	16.43
Marin county:																
San Rafael	25	*a*12	3	9.40	5.37	5.45	3.94	1.19	0.40	T.	....	0.34	2.30	4.69	6.32	39.40
Mendocino county:																
Camp Wright	1,800	*a*10	6	8.92	6.50	5.22	1.96	0.64	0.24	0.01	0.02	0.40	1.23	6.83	11.42	43.39
Point Arena	156	14	4	6.30	4.61	5.02	2.87	1.05	0.37	0.08	T.	0.31	1.78	3.20	5.23	30.77
Merced county:																
Merced	171	*a*18	5	2.10	1.22	1.33	1.22	0.43	0.17	0.01	T.	0.12	0.44	1.40	1.77	10.30
Modoc county:																
Fort Bidwell	4,640	*a*24	2	4.24	2.52	2.60	1.65	1.42	1.00	0.28	0.19	0.37	1.02	2.16	3.39	20.84
Monterey county:																
Monterey	42	27	0	3.03	2.55	2.80	1.53	0.33	0.15	0.04	0.02	0.08	0.66	1.55	3.54	16.28
Soledad	188	*a*16	6	2.10	1.61	1.64	0.65	0.25	0.10	T.	T.	0.03	0.41	1.04	1.59	9.42
Napa county:																
Calistoga	331	*a*17	11	6.76	4.52	4.74	2.68	0.89	0.30	0.01	T.	0.25	2.28	3.48	6.16	32.07
Nevada county:																
Boca	5,531	*a*19	10	4.25	3.10	2.61	1.28	0.54	0.14	0.18	0.02	0.03	0.52	1.06	3.19	16.92
Nevada city	2,500	22	10	10.93	7.68	8.57	5.15	2.06	0.60	0.04	0.04	0.54	2.25	6.77	12.09	56.72
Placer county:																
Auburn	1,360	*a*20	11	6.03	4.85	4.81	3.40	1.32	0.42	0.02	0.01	0.33	1.50	3.59	6.18	32.55
Summit	7,017	*a*20	6	7.77	7.27	7.47	4.84	1.84	0.73	0.39	0.03	0.21	2.23	3.37	7.51	43.65
Plumas county:																
Mumford Hill	4,900	5	8	13.08	12.33	10.71	7.56	2.96	0.56	0.14	0.32	0.69	2.23	4.10	11.12	65.80
Sacramento county:																
Folsom	182	*a*19	6	4.33	3.43	3.30	2.33	0.99	0.25	0.02	T.	0.25	1.23	2.58	4.62	23.33
Sacramento	64	*a*41	0	3.78	2.80	2.73	1.85	0.74	0.12	0.02	....	0.12	0.79	2.14	4.71	19.80
San Benito county:																
Hollister	284	*a*16	10	2.54	1.74	1.86	1.13	0.41	0.16	0.02	T.	0.09	0.66	1.42	1.87	11.90
San Bernardino county:																
Riverside	850	*a*9	10	1.62	1.94	2.14	1.07	0.31	0.07	....	0.33	0.02	0.37	0.83	2.04	10.74
San Bernardino	950	19	8	3.52	3.11	2.51	1.68	0.49	0.07	0.03	0.10	0.05	0.52	1.70	3.38	17.16
San Diego county:																
Fort Yuma	276	*a*26	7	0.31	0.39	0.14	0.07	....	....	0.33	0.66	0.58	0.09	0.30	0.29	3.16
Indio	20	*a*12	8	0.65	0.46	0.18	0.06	0.04	....	....	0.08	T	0.07	0.27	0.74	2.55
San Diego	93	*a*40	11	1.66	2.00	1.29	0.72	0.33	0.07	0.06	0.14	0.07	0.34	1.05	2.13	9.86
San Francisco county:																
San Francisco	60	41	0	5.10	3.60	3.26	1.93	0.07	0.15	0.02	0.02	0.16	0.98	2.87	5.32	24.08
San Joaquin county:																
Lathrop	25	*a*13	0	2.07	1.68	1.61	1.51	0.57	0.11	....	....	0.13	0.52	1.40	2.28	11.88
Stockton	20	*a*23	11	2.46	2.26	1.85	1.38	0.56	0.12	0.01	....	0.07	0.48	1.25	2.74	13.18
San Luis Obispo county:																
San Luis Obispo	270	*a*20	4	4.64	3.78	3.02	1.07	0.32	0.12	T.	....	0.12	1.05	2.01	4.50	21.53
San Mateo county:																
Pilarcitos	620	20	0	11.02	8.77	7.86	4.03	1.79	0.49	0.03	T.	0.39	2.01	6.09	12.35	54.83
San Mateo	30	*a*16	10	4.14	2.80	2.99	1.91	0.52	0.20	T.	T.	0.17	1.16	2.18	3.60	19.67
Santa Barbara county:																
Santa Barbara	20	*a*23	1	3.90	3.62	2.18	1.44	0.33	0.11	T.	T.	0.04	0.80	1.75	4.02	18.19
Santa Clara county:																
Mount Hamilton	4,440	*a*9	7	4.48	4.50	5.38	3.93	1.74	0.66	T.	0.02	0.24	1.75	1.92	9.80	34.42
San Jose	94	*a*16	6	2.75	2.25	2.61	1.43	0.47	0.18	T.	....	0.13	0.86	1.42	2.42	14.52
Santa Cruz county:																
Santa Cruz	25	*a*16	5	5.37	2.88	3.58	2.49	0.67	0.30	0.01	0.01	0.32	1.95	3.20	5.03	25.81
Shasta county:																
Fort Crook	3,390	*a*10	3	3.16	3.78	4.00	1.60	1.25	0.72	0.24	0.01	0.53	1.00	2.82	5.39	24.50
Redding	556	*a*15	7	6.34	4.29	4.82	3.35	1.62	0.54	0.04	0.06	0.33	2.60	3.68	6.93	34.60
Siskiyou county:																
Scott Valley	2,570	30	7	5.37	3.14	2.58	1.84	1.13	0.57	0.51	0.17	0.40	1.26	3.07	5.14	25.18
Yreka	2,635	18	7	3.25	2.16	1.44	1.08	1.09	0.58	0.46	0.12	0.31	1.30	1.86	2.69	16.34
Solano county:																
Benicia Barracks	64	*a*35	6	3.26	2.28	2.48	1.47	0.53	0.11	0.01	0.01	0.09	0.72	1.87	3.44	16.27
Vacaville	175	*a*11	10	5.31	3.32	3.94	2.79	1.56	0.19	....	....	0.24	1.63	3.26	7.40	29.64
Sonoma county:																
Petaluma	10	*a*18	0	5.16	3.57	3.10	2.02	0.75	0.30	T.	T.	0.19	1.42	2.50	4.65	23.76

a Record broken.

MEAN MONTHLY AND ANNUAL RAINFALL AT STATIONS IN CALIFORNIA—Continued.

LOCALITIES.	Altitude.	Length of record.		January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
	Feet.	*Yrs.*	*Mos.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Stanislaus county:																
La Grange	250	*a*20	11	2.79	2.63	2.56	1.55	0.60	0.05	T.	T.	0.28	0.88	2.28	2.99	16.61
Turlock	106	11	5	1.40	1.17	1.28	1.42	0.47	0.17	T.	....	0.19	0.63	1.80	1.75	10.28
Sutter county:																
Nicolaus	42	*a*11	8	3.36	2.44	2.62	2.76	0.54	0.40	T.	T.	0.26	0.75	2.00	3.42	18.55
Tehama county:																
Red Bluff	342	18	6	4.37	3.41	2.93	1.98	0.94	0.45	0.11	0.04	0.40	1.58	3.13	4.45	23.79
Tehama	220	*a*18	7	2.75	2.10	2.31	1.24	0.56	0.26	0.05	0.04	0.15	1.24	1.87	3.23	15.80
Trinity county:																
Weaverville	2,162	12	8	7.64	6.01	3.83	3.01	1.44	0.70	0.10	0.45	0.49	2.13	6.14	6.37	38.31
Tulare county:																
Goshen	286	*a*13	6	1.12	1.18	1.12	1.13	0.32	0.07	....	....	0.10	0.63	0.80	1.50	7.97
Tulare	289	16	3	1.48	1.07	0.96	0.96	0.38	0.08	0.05	....	0.02	0.40	0.52	1.08	7.00
Ventura county:																
San Buena Ventura	50	*a*11	0	3.65	2.83	1.98	1.61	0.15	0.03	0.17	0.01	0.13	0.31	3.28	3.72	17.87
Yolo county:																
Davisville	51	*a*18	10	3.30	2.17	2.21	1.58	0.58	0.14	0.01	T.	0.12	0.87	1.78	3.98	16.74
Knight Landing	35	*a*12	10	2.84	2.35	2.52	2.09	0.80	0.30	T.	T.	0.19	0.82	1.99	3.30	17.20
Yuba county:																
Marysville	67	*a*19	4	3.40	2.45	2.40	1.55	0.75	0.31	0.01	T.	0.18	1.16	1.90	3.89	18.09
Smartville	800	*a*9	9	7.11	5.70	4.48	2.85	0.79	0.40	0.04	....	0.10	1.35	3.35	4.51	30.68

a Record broken.

STATE INVESTIGATIONS.

A careful examination of the water supply in the Sacramento and San Joaquin basins was begun in June, 1878, by the state engineering department of California. Surveys were made for the purpose of obtaining facts bearing upon the solution of problems relating to drainage, river improvement, mining detritus, and irrigation, this work being carried on through a number of years. The state engineer published a number of annual reports, giving in detail the operations of his department, and also a preliminary volume of results. (*a*) In the following pages reference will be made frequently to this collection of statistics. He also prepared two volumes, one entitled "Irrigation Development" (*b*), the other "Irrigation in Southern California".

As one of the results of the work of the state engineering department there are now available computations of the monthly discharge of many of the more important rivers and creeks whose waters are employed in irrigation, these data covering the period from November, 1878, to October, 1884. Since that time few, if any, measurements have been made other than observations of the height of water from day to day on the railroad bridges of the Southern Pacific railway.

IRRIGATION DISTRICTS.

The early growth and development of irrigation in California have been similar to that in other parts of the arid region in the general lack of system or broad plans. Small ditches have been built by farmers, acting singly or in concert, and these have been enlarged and extended from year to year. Corporations and wealthy land owners also have sought to increase the value of vast estates by constructing canals, and, in short, each owner or group of owners has consulted only the immediate advantages to be obtained. Added to the complications which have necessarily arisen has been the question of riparian rights, especially troublesome and vexatious as the use of water became more and more valuable. Relief was sought by the passage, in 1887, of what was known as the District law, creating irrigation districts, these being corporations of a public character, possessing powers sufficient to overcome the obstacles interposed by conflicting interests, and empowered each within its own borders to construct the best possible system for conserving and distributing the waters. The irrigation district is in some respects similar to a municipal organization, but it has a single aim, that of delivering water in sufficient quantities to all of the lands embraced within its borders, and for this ultimate end all of its resources and the efforts of its officers are to be bent.

The law provides for the creation of districts by petition addressed to the board of supervisors of the county and by ballot of the electors of the district sought to be established. The board of supervisors is compelled to set a day for the hearing of the petition upon notice given, and if the petition establishes the allegations the election is ordered. Provision is made for the defining of boundaries, election of officers, and other requisites. After a feasible system has been determined upon by a competent engineer the board of directors may submit to the people of the district the question as to whether all of the lands within the district shall be bonded in order to raise funds to construct the proposed works, purchase rights of way, or other property necessary for the completion of the required system of irrigation. If bonds are voted these are to be disposed of at not less than 90 per cent of their face value. The district officers are given powers sufficient to push forward the work of construction and to pay

---

[a] Physical Data and Statistics of California. Tables and memoranda of data collected and compiled by the state engineering department of California. William Ham. Hall, state engineer. Sacramento, 1886.

[b] Giving the history, customs, laws, and administrative systems relating to irrigation, water courses, and waters in France, Italy, and Spain.

for it from time to time by the sale of the requisite number of bonds, safeguards being provided for the protection of the district against loss or misappropriation of its funds.

To aid in the sale of district bonds a somewhat novel provision of law has been put into successful operation. The superior courts of each county are empowered to examine into the legality and technical completeness of the acts of the district officers as far as these concern the bonds, and to issue a decree confirming all proceedings leading up to the organization of the district and the issuance of its bonds. This act of confirmation is intended as a safeguard, and one which shall act as an inducement to investors to purchase this class of securities. The only question which should then arise in the mind of the possible purchaser should be as to whether the real estate offered as security was of sufficient value.

In the five years following the passage of this act upward of 40 irrigation districts have been formed or seriously proposed, and the greater number of these have completed their organization and offered bonds for sale. There has been considerable difficulty in disposing of these bonds for cash for various reasons, many of these growing out of the novelty of the matter. At first there was a long struggle in the court before the constitutionality of the act and its amendments was settled beyond question. The main point being triumphantly carried, there have been many details requiring exact interpretation and definition by legal decision. Meanwhile, in the practical operations of many of the districts, troubles and unforeseen contingencies have arisen which have tended to render capitalists unusually cautious and even timid. The management of affairs of this kind, although in theory not novel, has in operation developed peculiar features. Apparently in each community it should be easy to select men of intelligence to conduct the affairs of a municipal corporation, from which in many respects the irrigation district differs little, but unfortunately the election of district officials has not in many cases brought the best men to the front, and the consequence of intrusting large affairs in the hands of unskilled men has been too apparent.

One feature of the typical irrigation district in which it differs most widely from other public associations is the fact that it starts at once by attempting to raise an enormous sum of money and to expend it toward the completion of a gigantic project. Little opportunity is given for preliminary work and the acquisition of experience so necessary in all lines of business; in other words, there is not the slow growth often essential for the success of great enterprises. Men are suddenly called upon to supervise the disbursement of hundreds of thousands or even millions of dollars and to take in charge the business of a great corporation, their only preparation being that of a small farmer or professional man in a country town. There are none of the minor rules or precedents so essential to the conduct of the innumerable details of a great business, and the personal judgment of each officer must be constantly exercised. It has thus resulted that boards of directors have been accused of extravagance, incompetence, and failure to select the best projects, and as a result investors have feared to purchase bonds of certain districts through doubts as to whether the money would be applied in such manner as to increase the value of the land. It is of course assumed that the land and property of the district in its original condition is ample security for the bonds, but as a matter of fact the argument is constantly used that the money obtained through sale of the bonds will be used in such manner as to increase this security. (a)

---

[a] The accompanying table gives in alphabetical order the names of the irrigation districts whose organization has been completed in whole or in part, together with a few of the principal facts concerning their area and the amount of bonds voted and sold:

IRRIGATION DISTRICTS, AREA, AND BONDS VOTED AND SOLD.*

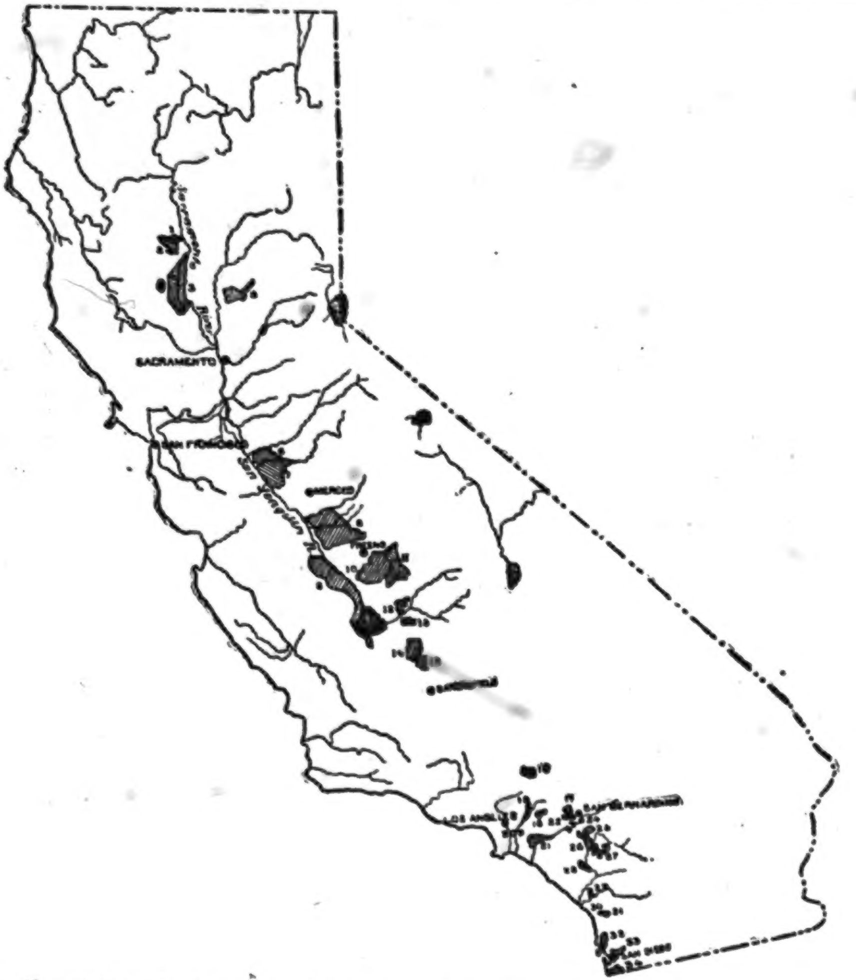
IRRIGATION DISTRICTS.	County.	Area in acres.	Bonds voted.	Bonds disposed of.
Alessandro	San Bernardino	25,500	$765,000	$765,000
Alta	Fresno and Tulare	129,927	675,000	528,000
Anaheim	Orange	32,500	600,000	300,000
Big Rock Creek	Los Angeles	30,000	400,000	100,000
Brown Valley	Yuba	44,000	140,000	140,000
Central	Glenn and Colusa	156,550	750,000	574,000
Citrus Belt	San Bernardino	12,000	800,000	
Colusa	Glenn and Colusa	100,000	600,000	
Debesia	Los Angeles			
East Riverside	San Bernardino	3,600	250,000	100,000
Elsinore	San Diego	11,300	452,000	
Escondido	do	12,814	450,000	
Fallbrook	do	12,000	400,000	
Glendora	Los Angeles	3,000	170,000	
Grapeland	San Bernardino	10,787	200,000	35,700
Happy Valley	Shasta			
Huron	Fresno	24,320		
Jamacha	San Diego	22,000	700,000	165,000
Kern and Tulare	Kern and Tulare	84,335	700,000	
Kraft	Tehama and Glenn	13,500	80,000	
Linda Vista	San Diego	42,000	1,000,000	180,000
Little Rock Creek	Los Angeles	2,000		
Los Angeles	do			
Madera	Fresno	330,000	850,000	
Manzana	Los Angeles	2,400		
Modesto	Stanislaus	80,564	800,000	370,000
Murrieta	San Diego	15,600		
Olive	San Bernardino	1,280		
Orland South Side	Glenn	26,000	$100,000	
Otay	San Diego	50,000		
Palmdale	Los Angeles	50,000	175,000	
Perris	San Diego	13,422	442,000	$314,500
Pomona Orange Belt	Los Angeles	4,000	200,000	
Poso	Kern	40,000	500,000	
Rialto	San Bernardino	7,200	500,000	500,000
Riverside Heights	do	8,500		
San Diego	San Diego			
San Jacinto and Pleasant Valley.	do	18,000	350,000	350,000
San Marcos	do	10,000		
Santa Fe	Los Angeles			
Santa Gertrudes	do	2,000		
Selma	Fresno and Tulare	271,000		
Spring Valley	San Diego	22,000		
Sunset	Fresno and Tulare	308,000	2,000,000	320,000
Tipton	Tulare	17,040	50,000	
Tulare	do	40,520	500,000	469,000
Tule River	do	20,000	90,000	
Turlock	Stanislaus and Merced	176,210	1,200,000	430,000
Vineland	Los Angeles	4,000	62,000	54,000
White River	Tulare			

* This table has been revised according to reports from irrigation districts published in "The Orange Belt", January, 1893, page 81.

In the five years following the passage of the District act it appears from the statements of district officials that only 2 districts have actually constructed and completed works for irrigation, and these 2 have been among those voting and selling the smallest amount of bonds. These are Brown Valley district, in Yuba county, and Vineland district, in Los Angeles county. The other districts which in this time have obtained water for irrigation, although not completing the works, are Alessandro, Alta, Citrus Belt, Perris, Rialto, and Tulare. Some of these, notably Alta district, have, however, purchased canals and means of supply already constructed. (*a*)

Several proposed districts have given up their organization or the acts of the directors have been declared illegal by court decision; in others projects have been attempted apparently too great for successful completion; but as a rule the districts have been as well managed as other corporations conducted by untried officials. Among the charges brought against district directors has been that of evading the spirit of that section of the law preventing the disposal of bonds at less than 90 per cent of their face value. It is asserted that in certain districts the evasion has been accomplished by trading bonds for water rights or work to which fictitious value has been given, two or three times the actual value of a canal or water right being paid in this manner. Such matters, however, are mostly of local concern and can be guarded against by the public interest and resulting criticism.

MAP SHOWING THE RELATIVE LOCATION OF IRRIGATION DISTRICTS OF CALIFORNIA.



The relative location of the principal irrigation districts is shown on the map, the size and shape of each district

---

[a] Mr. L. M. Holt, secretary of the convention of irrigation districts held in Sacramento January 6, 1893, stated publicly that out of 38 irrigation districts then in existence 19 reported having voted bonds to the extent of $11,834,000. Out of this, bonds amounting to $2,622,0[illegible] had been sold for cash and $2,995,200 had been traded for water rights, making in all $5,617,200 of bonds disposed of, a little less than one-half the amount voted by the 19 districts. Thirteen other districts had voted bonds amounting to $4,942,000, none of these being sold. These 32 districts which had voted bonds contained 1,830,760 acres, and the bonds averaged $9.16 per acre. The 38 districts then in existence contained 2,149,060 acres. Out of this number 28 districts, containing 1,515,594 acres, had an assessed valuation of $39,962,848, the assessed valuation being thus $26.38 per acre.

being indicated by the cross hatched areas. Opposite each of these is a number which refers to the following list, giving the name of the district, the county in which it is located, and the area in acres:

IRRIGATION DISTRICTS.	Counties.	Area in acres.
1. Kraft	Tehama and Glenn(a)	13,500
2. Orland South Side	Glenn	26,000
3. Colusa	Glenn and Colusa	100,000
4. Central	do	156,550
5. Brown Valley	Yuba	44,000
6. Modesto	Stanislaus	80,564
7. Turlock	Stanislaus and Merced	176,210
8. Madera	Fresno	330,000
9. Sunset	Fresno and Tulare	808,000
10. Selma	do	271,000
11. Alta	do	129,927
12. Tulare	Tulare	40,520
13. Tipton	do	17,040
14. Kern and Tulare	Kern and Tulare	84,335
15. Poso	Kern	40,000
16. Big Rock Creek	Los Angeles	30,000
17. Grapeland	San Bernardino	10,787
18. Pomona Orange Belt	Los Angeles	4,000
19. Vineland	do	4,000
20. Santa Gertrudes	do	2,600
21. Anaheim	Orange	22,500
22. Citrus Belt	San Bernardino	12,000
23. Rialto	do	7,200
24. East Riverside	do	3,600
25. Alessandro	do	25,500
26. Perris	San Diego	13,423
27. San Jacinto and Pleasant Valley	do	18,000
28. Elsinore	do	11,300
29. Fallbrook	do	12,000
30. San Marcos	do	10,000
31. Escondido	do	12,814
32. Linda Vista	do	42,000
33. Jamacha	do	22,000
34. Otay	do	50,000

[a] Glenn county created since 1890, taken from the northern part of Colusa county.

FRUIT CULTURE.

The wonderful success attained by the cultivation of fruit trees and vines by means of irrigation upon lands otherwise valueless and the great results from the reclamation of such lands, increasing them in value a hundred fold or more, have drawn public attention to irrigation more forcibly than any other results. It must not be supposed that horticulture in California by any means depends upon irrigation, for in many of the counties widely known for the production of excellent fruit the artificial application of water is almost unknown, but on the other hand there are counties now wealthy and prosperous in which the destruction of the canal systems and other means of distributing water would bring about ruin and desolation. It is from a consideration of these localities that the general impression is sometimes given that the fruit producing districts of the state, outside of the orchards and vineyards, are arid and forbidding.

Local details are given under the county descriptions on the following pages. As regards acreage of trees or vines, raisins lead, followed at a considerable distance by the acreage of orange trees, peaches, and prunes. Experiment and intelligent observation in each county, aided by discussions at horticultural conventions, are rapidly bringing to light the varieties best suited for the different climates and soils and the best methods of cultivation and protection from insect and other pests. To the majority of orchardists the subject of irrigation, although as fundamental as that of supplying water to their families, is a matter of little concern in comparison with that of protecting their trees and vines from blight and disease, but it is generally recognized that the extension of area of productive lands will come largely through this means.

CONDITION OF IRRIGATION IN EACH COUNTY.

In the table on the following page, which contains the name of each county in the state, are given the facts concerning the number of irrigators, the area irrigated, and the average size of irrigated farms in the census year. Among these 53 counties there are included 10 in which no irrigated farms were reported. These are Alameda, Contra Costa, Del Norte, Marin, Napa, San Luis Obispo, San Mateo, Solano, Sonoma, and Sutter, counties located mainly along the coast or adjoining the bay of San Francisco. As previously stated, irrigation has not been practiced to any notable extent in these 10 counties, because fruits and vegetables, as well as field crops, are grown successfully without the artificial application of water. There may be a few exceptional cases where small orchards and vineyards are occasionally watered by means of machinery, driven by windmills or other devices, but these can hardly be classed as irrigation.

NUMBER OF IRRIGATORS, AREA IRRIGATED, FARMS, AND CROPS, IN EACH COUNTY IN CALIFORNIA IN 1889.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.	OWNERS OF FARMS. (a)		IRRIGATORS.		Area of county in acres.	FARM AREA.		Cereals. (Acres.)	Alfalfa. (Acres.)	AREA IRRIGATED.		
				Total number.	Per cent of population.	Per cent of farm owners.	Per cent of population.		Acres.	Per cent improved.			Per cent of area of county.	Per cent of total farm area.	Per cent of land owned by irrigators.
Total	13,732	1,004,233	73	52,894	4.38	25.96	1.14	99,827,200	21,427,293	57.04	3,812,751	245,915	1.01	4.69	17.88
Alameda	......	......	......	1,822	1.94	......	......	450,560	298,846	74.58	45,782	54	......	......	......
Alpine	31	2,680	86	31	4.65	100.00	4.65	483,200	9,780	45.50	459	120	0.55	27.40	27.40
Amador	221	3,136	14	700	6.78	31.57	2.14	363,520	208,172	34.19	9,058	2,467	0.86	1.51	5.08
Butte	372	5,478	15	1,186	6.61	31.37	2.07	1,100,800	504,538	71.41	170,595	18,761	0.50	1.09	4.05
Calaveras	57	582	10	483	5.44	11.80	0.64	627,200	148,560	47.20	3,293	523	0.09	0.39	4.92
Colusa	93	7,525	81	1,028	7.02	9.05	0.64	1,568,000	947,582	81.51	274,040	3,854	0.48	0.79	7.41
Contra Costa	......	......	......	1,069	7.91	......	......	518,400	296,093	87.89	59,176	110	......	......	......
Del Norte	......	......	......	112	4.32	......	......	960,000	33,491	45.04	579	2	......	......	......
Eldorado	425	4,318	10	744	8.06	57.12	4.60	1,145,600	177,302	29.10	7,325	416	0.38	2.44	4.57
Fresno	1,400	105,665	75	2,350	7.34	59.57	4.37	5,126,400	1,373,339	69.28	492,933	17,401	2.06	7.69	15.48
Humboldt	18	89	5	1,232	5.25	1.46	0.08	2,284,800	547,792	69.49	10,097	626	......	0.02	0.46
Inyo	209	46,242	221	225	6.35	92.89	5.90	6,412,800	68,256	67.75	4,211	6,664	0.72	67.75	69.63
Kern	370	154,549	418	730	7.44	50.68	3.77	5,101,440	712,130	19.61	21,127	36,642	3.03	21.70	16.13
Lake	68	958	14	664	9.35	10.24	0.96	720,000	203,062	51.94	10,757	3,971	0.13	0.47	3.75
Lassen	293	55,819	190	507	11.96	57.79	6.91	3,129,600	242,361	41.65	9,828	2,214	1.78	23.03	23.81
Los Angeles	1,843	70,164	38	3,828	3.77	48.15	1.82	2,560,000	759,933	57.48	143,696	10,181	2.74	9.23	21.70
Marin	......	......	......	422	3.23	......	......	377,600	257,717	74.22	1,763	......	......	......	......
Mariposa	90	730	8	384	10.14	23.44	2.38	1,004,800	144,889	25.55	3,309	3,045	0.07	0.50	3.28
Mendocino	19	77	4	932	5.29	2.04	0.11	2,364,160	572,875	27.81	11,089	1,042	......	0.01	0.66
Merced	231	32,309	140	798	9.87	28.95	2.86	1,452,800	878,958	71.29	294,357	8,124	2.22	3.68	13.38
Modoc	402	80,110	199	613	12.29	65.58	8.06	2,686,720	251,909	62.46	7,627	1,080	2.98	31.80	45.07
Mono	94	43,523	463	103	5.14	91.26	4.70	2,165,760	79,523	64.10	229	1,695	2.01	54.73	54.74
Monterey	21	891	42	1,673	8.98	1.26	0.11	2,209,280	1,045,212	45.86	195,529	164	0.04	0.09	3.13
Napa	......	......	......	1,204	7.34	......	......	544,000	288,747	51.02	23,688	686	......	......	......
Nevada	318	3,990	13	601	3.46	52.91	1.83	640,000	117,877	28.05	259	511	0.62	3.38	5.72
Orange	1,030	31,816	31	1,406	10.35	73.90	7.65	473,600	265,240	72.60	14,596	3,386	6.72	12.00	21.16
Placer	431	7,480	17	1,023	6.77	42.13	2.85	954,880	278,706	50.24	29,485	13,561	0.78	2.68	9.51
Plumas	186	34,196	184	210	4.26	88.57	3.77	1,740,800	125,957	83.21	4,589	377	1.96	27.15	29.37
Sacramento	146	1,718	12	1,285	3.19	11.36	0.36	646,400	439,450	77.73	114,130	8,787	0.27	0.39	6.22
San Benito	77	905	12	740	11.54	10.41	1.20	640,000	484,361	55.80	48,268	553	0.14	0.19	1.99
San Bernardino	1,521	37,907	25	1,924	7.55	79.05	5.97	13,440,000	307,845	41.09	21,838	6,555	0.28	12.31	17.65
San Diego	524	10,193	19	2,474	7.07	21.18	1.50	9,310,720	887,796	26.91	47,138	4,277	0.11	1.15	3.77
San Francisco	52	479	9	145	0.05	35.86	0.02	32,000	3,469	89.45	15	4	1.50	13.81	49.43
San Joaquin	84	2,254	27	1,380	4.82	6.09	0.29	883,200	571,271	97.99	306,567	4,097	0.26	0.39	4.61
San Luis Obispo	......	......	......	1,788	11.12	......	......	2,178,560	1,084,398	25.19	52,597	242	......	......	......
San Mateo	......	......	......	602	5.97	......	......	294,400	168,033	69.97	5,290	34	......	......	......
Santa Barbara	47	396	8	853	5.41	5.51	0.30	1,523,200	521,270	45.50	33,147	1,938	0.03	0.08	1.01
Santa Clara	184	6,686	36	2,177	4.53	8.45	0.38	883,200	445,535	63.15	48,228	429	0.76	1.50	21.82
Santa Cruz	23	374	16	916	4.75	2.51	0.12	272,000	126,021	69.41	12,521	1,221	0.14	0.30	7.71
Shasta	475	13,662	29	950	7.83	50.00	3.91	2,534,400	281,370	31.47	12,936	1,675	0.54	4.86	9.86
Sierra	86	14,499	169	107	2.12	80.37	1.70	576,000	44,505	49.43	3,115	141	2.52	32.51	37.14
Siskiyou	302	31,567	105	517	4.25	58.41	2.48	3,635,200	228,993	39.73	12,807	7,631	0.87	13.79	23.73
Solano	......	......	......	1,213	5.79	......	......	614,400	431,910	84.84	107,791	103	......	......	......
Sonoma	......	......	......	2,886	8.82	......	......	990,720	797,053	43.57	28,806	2,827	......	......	......
Stanislaus	42	3,370	80	713	7.10	5.89	0.42	951,040	741,468	88.21	344,803	3,408	0.35	0.45	8.64
Sutter	......	......	......	642	11.74	......	......	377,600	257,956	87.61	92,709	3,306	......	......	......
Tehama	116	7,169	62	781	7.88	14.85	1.17	1,912,320	864,666	45.76	97,390	5,515	0.37	0.83	2.80
Trinity	140	3,186	23	220	5.92	63.64	3.76	1,920,000	67,757	18.63	1,286	735	0.17	4.70	11.87
Tulare	1,287	168,455	131	2,193	8.92	58.69	5.24	3,578,880	928,677	63.33	319,405	32,426	4.71	18.14	34.03
Tuolumne	100	1,285	13	219	3.60	45.66	1.64	1,310,720	68,128	34.48	3,154	16	0.10	1.89	4.52
Ventura	134	3,347	25	764	7.59	17.54	1.33	1,076,480	324,529	42.32	66,223	4,461	0.31	1.03	7.90
Yolo	39	1,602	41	866	6.83	4.50	0.31	622,080	375,664	82.23	144,490	12,553	0.26	0.43	11.39
Yuba	122	2,852	23	459	4.76	26.58	1.27	456,960	226,231	73.34	38,538	5,245	0.62	1.26	6.62

a Includes owned and hired farms, assuming one farmer to each.

ALAMEDA COUNTY includes a large part of the area immediately west of the bay of San Francisco, containing within its limits the city of Oakland. It is noted for the large quantities of fruit produced, many of its wheat fields having been cut up and planted in orchards and vineyards. Besides the arable areas along the shore, there are a number of inland valleys in which agriculture and fruit raising are carried on. Irrigation is not practiced to any considerable extent, and the few gardens or nurseries to which water is occasionally applied were not considered of sufficient area to justify enumeration. One irrigating ditch known as the Washington and Murray was constructed about 1875, taking water from the west side of Alameda creek and conducting it for 3 or 4 miles. The control of this ditch has been acquired by the Spring Valley Water Company of San Francisco. Some of the farmers under the ditch state that irrigation was of doubtful benefit, at least for the crops they were raising.

ALPINE COUNTY includes a portion of the mountain area south of Lake Tahoe and adjoining Douglas county, Nevada. Owing to the altitude and lack of communication the principal industry is stock raising. In some of the valleys dairy products assume importance, these being shipped by way of Carson, Nev. There are a number of small ditches taking water from the upper tributaries of the Carson river and carrying it to the meadow lands of Hope, Faith, and Charity, Diamond, Hermit, and Pleasant valleys. There are numerous localities in this county where water could be held for use on the fertile lands of Nevada, and probably a number of these would be utilized for storage purposes were it not that the catchment basin of the Carson river lies in two states differing in laws and customs.

Amador county occupies a narrow belt of country west of Alpine county, extending from the summits of the Sierra Nevadas westward to the Sacramento valley, between the Mokelumne and the south fork of the Cosumnes. The eastern part of the county is exceedingly rugged, while the western portion contains a number of valleys in which agriculture is carried on. The principal industry is mining, and nearly all of the ditches have been built for use in connection with mines and mills, although some of the water is now employed for irrigation. The cereals are seldom watered, the farmers stating that crops are successful by dependence upon the rainfall, and that the extra labor and expense of applying water would hardly be justified by the probable increased returns. In fact, irrigation can not be considered as essential in this county, although there are localities where it is employed to profit, as shown by one statement that land planted in grain not irrigated would yield from $10 to $12 per acre, but when irrigated and covered with alfalfa would yield $30 per acre, or in fruits from $50 to $100 per acre.

The principal fruits raised are peaches, apricots, apples, prunes, and pears, mainly in Lone and Jackson valleys and adjacent localities. The orchards are cultivated largely without irrigation, although water is used where it can be obtained at reasonable cost. Water is usually sold by the miner's inch per day, the charge varying from 5 cents up to 25 cents per day. In the first instance it was considered that the irrigation season lasted for 130 days, so that the charge per miner's inch for the season was $6.50. In the other instance water was only used 4 days during the year. In all of these estimates of quantity the miner's inch is so variable that the quantity actually delivered may in one case be two or three times that in another.

Butte county is in the northern part of the Sacramento valley, being on the east of the river of that name and extending easterly up the slopes of the Sierras. The western part of the county includes a large portion of the broad valley land between the Feather and Sacramento rivers, this area being utilized largely for the production of cereals and other field crops. Near and among the foothills the soil and climate have been found to be exceptionally favorable for fruit culture, and much of the rolling land to which water can be conducted is being set out to orchards and vineyards. The principal locality in which irrigation is conducted is in the vicinity of Oroville, where a number of colonies depending almost entirely on fruit culture have been started. The water supply of the county as a whole is large, although during summer most of the smaller streams become dry. From about 1855 to 1860 and during later years large and expensive systems of ditches and flumes were constructed for the purpose of bringing water, mainly from the upper tributaries of Feather river, to the gravel or placer mines among the foothills. With the decline of hydraulic mining these ditches would have become almost useless were it not for the growth of the fruit industry.

Irrigation is not required for wheat and other of the cereals, excepting perhaps Indian corn, but in most localities it is indispensable for orchards, vineyards, and alfalfa. Some of the orchardists claim that fruit not grown by irrigation, but produced in localities where the soil is deep, somewhat moist and well cultivated, is better in that it shrinks less in drying and can be transported with less loss. Land among the foothills without water is worth from $10 or under up to $30 per acre, but with water is valued at $100 per acre and upward. Attempts have been made to obtain flowing wells, but with little success. At Oroville a well was drilled to the depth of 800 feet at a cost of $2,000 or over. It flows at the rate of only 4 gallons a minute. The water contains a perceptible amount of mineral matter commonly known as soda, and there is also a small quantity of gas issuing from the well. The owner states that if the well were properly cased the supply would probably be increased. About 4 miles north of Chico a well has been drilled to the depth of 686 feet without obtaining artesian water.

The Thermalito canal has resulted from the utilization of four ditches formerly used for mining purposes, and known as the West, or Powers, Flea Valley, Miocene, and Mineral Slide, or Snow, ditches. It obtains water from the west branch of the north fork of Feather river, carrying it out on the west side to the vicinity of Oroville. The principal head dam is about 25 miles north of Oroville, this being designed for permanent use. The total length of the main ditch is 33 miles, the average width from 5 to 8 feet, and the original cost was over $500,000. The earliest of the ditches was begun in 1852. There are on the line of the canal 800 feet of tunnel, 4 miles of wooden flumes, and 3 miles of 22-inch iron pipe. Water is sold usually under annual contracts at $2.50 per acre for orchards and $5 per acre for alfalfa and vegetables. It is computed that the water duty is at the rate of 1 miner's inch for 5 acres of orchard or 2.5 acres of alfalfa.

The canal of the Palermo Land and Water Company takes water from the south branch of Feather river, the head being about 1.5 miles above the town of Enterprise. The canal is located on the south side of Feather river, and continues in a southwesterly direction for 22 miles from the head to Oroville, then turning southerly toward Palermo. The total length of the main ditch is about 25 miles, the average width 9 feet, and the total cost was $200,000. Along the line of the canal are nearly 4 miles of flumes, 72 inches wide and 24 inches high. There are five branch ditches, with a capacity, respectively, of 12, 8, 4, 5, and 6 second-feet. Water is measured under a 6-inch pressure, and sold at the rate of 10 cents per miner's inch for 24 hours, or $5 per second-foot for the same time.

The ditch owned by the South Feather Water and Union Mining Company takes water from Lost creek, a branch of the south fork of Feather river, the head being about 2 miles west of the town of Strawberry Valley. The ditch is built on the south side of the river, the water flowing in a general westerly direction. The total length of the main ditch is 25 miles and the average width 8 feet. From the head down to Forbestown, a distance of 18 miles, the ditch, 10 feet wide on top and 6 feet wide on bottom, is built along the steep mountain side through a very rough country. There are nearly 3 miles of flumes and 2 tunnels. Water, as in the case of many of the other companies, is sold at the rate of 10 cents per miner's inch per 24 hours, and is used mainly for fruit and vegetables. This ditch system was originally built for mining, but since the exhaustion of the shallow deposits among the foothills and the suppression of the large hydraulic mines the water has gradually been utilized for irrigation. The irrigating season extends usually from about the middle of May to the middle of September.

The Cherokee ditch, belonging to the Spring Valley Gold Company, takes water from Butte creek near the northern edge of the county. The total length of the ditch is about 40 miles, the average width 5.5 feet on bottom and 8 feet on top, and the cost was about $200,000. In the course of the ditch there are about 2 miles of flume and 2.5 miles of 36-inch iron pipe, the latter carrying water across the west branch of Feather river under a nearly vertical pressure of about 1,000 feet. This ditch has been used exclusively for hydraulic mining, but this being stopped by the operations of law it is proposed to utilize the water for irrigation.

CALAVERAS COUNTY is south of Amador, and, like it, extends from the summits of the Sierra Nevadas down the slopes to the San Joaquin valley. Mining has always been the principal industry, and upon this agriculture has been dependent largely for its markets. Nearly all the farmers are interested to a greater or less extent in stock raising, and many of the cereals are produced for hay. Irrigation, although not essential, is practiced to a notable extent, mainly for fruit trees. The miners have constructed elaborate systems of ditches, and from these water can be obtained in many localities at rates of from 10 to 15 cents per miner's inch for 24 hours. In one case at least it is stated that during the season 8 miner's inches flowing for 24 hours furnished sufficient water for each acre, the water, of course, being applied at different times. At 15 cents per miner's inch this would make the annual charge only $1.20 per acre. The water supply is large, as can be seen by examining the tables of discharge of the Calaveras and other rivers, as given in descriptions of San Joaquin county.

COLUSA COUNTY (*a*) includes a large part of the valley west of the Sacramento river. It thus consists mainly of a broad plain sloping gently toward the south. Besides the general fall along the valley there is also a gentle slope from the foothills toward the river, and also, as is sometimes found in great valleys, a slight rise to the river banks, so that the lowest ground is parallel to the stream and at a distance of some miles from it. In other words, this river has built up for itself a broad, low ridge, upon the top of which is the main channel. This feature renders the diversion of water for irrigation comparatively easy, since, aided by the general fall toward the south, canals can be made to conduct the water far away from the river across the plains to points near the foot of the bounding hills.

The county as a whole has the reputation of being one of the greatest wheat producing areas of the world, the level surface and uniform richness of soil rendering possible farming operations by machinery and on an enormous scale. With the low price of wheat even this wholesale farming can hardly be said to be profitable at all times, and steps have been taken, as in the San Joaquin valley, to introduce irrigation in order to insure the profitable cultivation of fruit. For the ordinary field crops the artificial application of water is not essential, although often desirable, and some of the lands of the county in fact need drainage rather than irrigation. Where practiced, the application of water is generally by flooding, the water flowing from one check or levee to the next and covering the intervening ground.

The principal source of water supply of these counties is the Sacramento, the waters of which, owing to the peculiar topography, can be brought out to the base of the foothills, covering the entire plain. The small streams coming in from the west, although intermittent in character, also furnish some water, which, especially by storage, could be used in irrigation. Stony creek, which flows easterly near the north line of the county, has a relatively large catchment area and supplies a number of ditches among the foothills and also above Orland. The quantity of water in the Sacramento river at Sacramento, 30 miles below the southern line of the county, has been ascertained by the state engineering department of California, the results being published in the volume of physical data and statistics. From these figures estimates have been prepared of the probable quantity at the head of the main canal of the Central irrigation district, which is at the south line of Tehama county. The results obtained are given in the table on the following page.

---

[a] In 1891 this county was divided, the northern part being set off and given the name of Glenn. In this discussion the two counties are included, since the census statistics apply to the condition of things before the division.

DISCHARGE IN SECOND-FEET OF THE SACRAMENTO RIVER AT SACRAMENTO, CALIFORNIA. (a)

[For each month from 1879 to 1885, and at proposed head of Central District canal for each month when the flow was approximately less than 6,040 second-feet during the same period.]

MONTHS.	1879		1880		1881		1882		1883		1884		1885	
	At Sacramento.	At head of Central canal.	At Sacramento.	At head of Central canal.	At Sacramento.	At head of Central canal.	At Sacramento.	At head of Central canal.	At Sacramento.	At head of Central canal.	At Sacramento.	At head of Central canal.	At Sacramento.	At head of Central canal.
January	12,000	6,040	28,000	....	95,000	....	24,000	....	12,000	6,040	12,000	6,040	90,000	....
February	30,000	....	21,000	....	115,000	....	22,000	....	17,000	....	24,000	....	52,000	....
March	110,000	....	22,000	....	77,000	....	55,000	....	21,000	....	80,000	....	30,000	....
April	110,000	....	95,000	....	90,000	....	90,000	....	73,000	....	105,000	....	29,000	....
May	75,000	....	135,000	....	70,000	....	92,000	....	80,000	....	111,000	....	23,000	....
June	45,000	....	110,000	....	25,000	....	74,000	....	32,000	....	90,000	....	14,000	....
July	16,000	....	53,000	....	14,000	....	17,000	....	12,000	6,040	31,000	....	6,500	3,960
August	8,500	4,960	18,000	....	8,000	4,740	8,000	4,740	7,000	4,240	12,000	6,040	5,500	3,340
September	6,500	3,960	9,000	5,160	6,500	3,960	6,500	3,960	6,500	3,960	7,500	4,500	5,200	3,070
October	8,000	4,740	7,500	4,500	7,000	4,240	10,000	5,500	7,000	4,240	8,000	4,740	5,200	3,070
November	7,500	4,500	7,000	4,200	8,200	4,780	14,000	....	7,500	4,500	7,000	4,240	....	....
December	27,000	....	20,000	....	16,000	....	11,000	5,790	7,400	4,475	31,000	....	....	....

a During the months for which approximate figures are not given for the point "At head of Central canal" the discharge of the river there was manifestly so far in excess of the canal's utmost capacity that it were idle to make any comparison, and so reductions from the Sacramento station records were not attempted. (From report on the Central Irrigation district, California; its physical, engineering, and business problems and conditions. William Ham. Hall. San Francisco.)

The principal irrigation works in this county are those of the Central irrigation district, mentioned below. In addition to this large canal, which is not yet in practical operation, there are a number of ditches taking water from Stony creek and other streams, and also what are known as high water or overflow canals leading from the Sacramento to the lower grounds back from the river banks. These high water ditches, as their name implies, receive water only in times of flood. As an example of each of these classes of irrigation works the following descriptions may suffice. The Carver ditch takes water from the west side of Big Stony creek to irrigate lands south of the town of Elk Creek. The length is 1.3 miles, width 8 feet, and the cost was about $2,000. During the census year only about 20 acres were irrigated, 3 of these being in orchards, 8 in corn, and 9 in alfalfa.

The Cheney Slough Water and Irrigation ditch takes water from the west side of the Sacramento river, about 6 miles north of Colusa. The total length is about 10 miles, the width 40 feet, and the cost was approximately $10,000. The head gate consists of an iron pipe 4.5 feet in diameter and 50 feet in length, laid in masonry and placed 6 feet below the top of the river bank. For the canal itself an old slough was utilized, after having been scraped out and otherwise improved. There are about 20 distributaries of from 0.2 to 1 mile in length and from 4 to 6 feet in width. The works are owned by an association of land owners. Irrigation can be practiced only when the river is very high, as it is at times in the winter season, and thus it is rarely possible for the land to receive more than one thorough flooding during the year. At that time the ground is covered to the depth of from 1 foot to 1.5 feet. The principal crops raised are wheat, barley, and alfalfa. Along the river there are a number of similar devices for flooding the lowlands during the time of high water, and in addition to these are several pumping plants for the purpose of irrigating orchards and gardens during the long dry season. One instance is given of a 7-inch centrifugal pump run by a 40-horse power engine pumping from an 18-inch well 34 feet in depth. The delivery is estimated to be 120,000 gallons per hour, and with this quantity 10 acres are irrigated in 12 hours, the water being applied by means of furrows 16 inches wide, 6 inches deep, and 4 feet apart.

A number of irrigation districts have been formed in this county, mainly in the northern part. The most northerly of these is the Kraft irrigation district, lying on the north side of Stony creek. South of this is the Orland South Side Irrigation district, water for which is diverted from the south side of Stony creek, canals being projected to cover land west and south of Orland. Still farther south is the Central irrigation district, one of the largest in the state. East of this, and between it and the Sacramento river, is the Colusa district, a narrow body of land from 3 to 5 miles in width.

The Central irrigation district shown on the preceding map embraces 156,550 acres, or nearly 245 square miles. Of this amount over 140,000 acres have been cultivated for cereals. In general shape, the district is long and narrow, being 38 miles from north to south, and in general from 6 to 9 miles in width. Water for irrigation is to be obtained from the Sacramento, the diverting canal heading at the Tehama county line and continuing southerly and southwesterly to Willows, and thence southerly along the edge of the foothills. The capacity of the main canal as projected is about 750 second-feet. As planned, this main canal will be nearly 62 miles in length and 60 feet in bottom width near the head, narrowing to 50 and then to 25 feet. There will be upward of 200 miles of distributary canals and ditches, of from 8 to 20 feet bottom width. In order to build this system bonds to the amount of $750,000 have been voted. Great difficulty has been experienced in selling these bonds, and as a consequence construction has not been pushed forward as rapidly as it otherwise would have been.

The district was formed in the fall of 1887, and from its inception has been bitterly fought by many of the land owners within its area. Many statements have been received from farmers to the effect that irrigation is not needed and that they are in danger of ruin from the results of the excessive taxation incident upon the district organization and work. In carrying out its plans also the district has encountered many unforeseen obstacles in obtaining rights of way, the condemnation proceedings being slow and expensive. It has been estimated by persons familiar with the conditions that the opposition alone has resulted in an unforeseen expenditure of at least $200,000.

The Kraft irrigation district as organized includes 13,500 acres, on which bonds to the amount of $80,000 were voted. So far as has been ascertained none of these have as yet been sold. The district extends along the north side of Stony creek, being thus partly in Tehama county. It averages 2 miles in width and is approximately 10 miles long. Water is to be obtained from Stony creek, which, however, is dry in its lower parts at least by June of each year. The Orland South Side Irrigation district comprises 26,000 acres. Bonds were voted, but by decision of court were declared void on account of irregularities. Persistent attempts have been made by many of the farmers in the district to put an end to the whole matter, and as a result, little, if anything, has been accomplished. The Colusa district, lying along the west side of the Sacramento, includes 100,000 acres, on which bonds to the amount of $600,000 were voted, but none were sold. No work has been done, and apparently all plans of irrigation have been abandoned.

Contra Costa county lies directly north of Alameda county, being between it and Suisun and San Pablo bays. On the east the county includes a large part of the tule or swamp lands at the mouth of the San Joaquin river, some of which have been reclaimed, forming farms of great value. Irrigation is not practiced, there being ample rainfall even among the valleys at the foot of Mount Diablo. As in the other bay counties, fruit culture is of great importance, large areas being planted in vines as well as in trees. The principal fruits are apricots, cherries, peaches, prunes, pears, and the so-called small fruits. Owing to its proximity to the city of San Francisco considerable areas on the lowlands are devoted to market gardening, but for this no irrigation is required as the soils are naturally moist.

Del Norte county is in the extreme northwestern corner of the state, extending from the Oregon line southerly along the coast to Klamath river and including nearly the entire catchment basin of Smith river, which drains a portion of the coast range. The greater part of the area is mountainous and heavily timbered, the valleys being narrow and containing little agricultural land. The rainfall is heavy and there is no need of irrigation, except perhaps for fruit trees during the summer drought. There is an area of farming lands near the coast in the vicinity of Crescent city, but here it may be said that drainage is more important than irrigation. Also in Smith River valley are a few farms, as well as in small valleys similar to the one at Gasquet. Here the only crops are hay and vegetables, together with a few acres of grapevines and fruit trees.

Eldorado county, lying north of Amador, extends from Lake Tahoe and the Nevada state line westerly down the slopes of the Sierra Nevadas to the plains in the vicinity of Sacramento, the state capital. It includes a large portion of the catchment basin of the American river and of the Cosumnes, the next important river on the south. Mining has been the principal industry, this portion of the state having become famous for the rich discoveries and heavy output of gold. Following the miners came the cattlemen, who found excellent grazing on the wild grasses covering the valleys and hill slopes. General agriculture has also been practiced to a considerable extent, and irrigation, although not strictly essential, has come to be of considerable importance. Some of the ditch systems built by the large mining companies rival in extent those of counties farther to the south. The more important of these are the works of the California Water and Mining Company, whose ditches cover Georgetown divide; the Eldorado Water and Deep Gravel Mining Company, and the Park Canal and Mining Company, covering portions of the county southerly from Georgetown. The amount charged for the use of water from these mining ditches varies considerably, but compared with the rest of the state seems high. The rates given are in different instances 12.5 cents per miner's inch for 12 hours, or from 20 cents up to 35 cents per miner's inch for 24 hours. There is general complaint that these prices are too high, and that if water could be obtained at lower rates it would be more generally used. By thorough cultivation excellent fruits, such as peaches, prunes, and cherries, are raised without irrigation, although it is probable that in many instances a larger yield could be obtained by proper application of water. Grain and the forage crops are seldom if ever watered, on account of the expense involved.

Fresno county is situated midway of the length of San Joaquin valley, and includes within its boundaries a greater portion of this valley than any of the neighboring counties. It extends from the summits of the Sierra Nevadas southwesterly down the slope of the range to and across the lowlands up to the hills on the west, and thus on the east embraces the catchment area of the head waters of the San Joaquin and Kings rivers. The broad valley lands of the southwestern half of the county have been found to have a soil and climate particularly adapted to the raisin grape and to the so-called deciduous fruits, rendering the production of these the chief industry of this great region.

The rivers on leaving the foothills spread out over the broad valley and, as is the case with most rivers in this part of the state, lose their waters in innumerable sloughs or in the pervious beds. The San Joaquin river, in the center of the county, may be considered as a notable exception, for this, by its strong perennial discharge, has cut for itself a more decided channel, in which it continues throughout its course in the county. The smaller streams, draining relatively a few square miles of mountain area, generally disappear altogether on reaching the lower ground, their waters passing by seepage down along the valley and giving rise to conditions favorable for artesian wells. There is one peculiarity of the soil of the San Joaquin valley, which is perhaps as well marked in the vicinity of Fresno as at any other point, and that is the power of receiving and transmitting water laterally for long distances. After a large area has been thoroughly saturated it is not necessary to apply water again to the surface, but the orchards and vineyards receive a sufficient amount of moisture through the percolation from canals at some distance away. The mechanical structure favorable for this transmission of water is not possessed by all the soils, but is peculiar to most of the good raisin land. The fact that the land does not require direct irrigation does not relieve the owner from the necessity of paying his annual dues of $1 or more per acre, for although he does not draw the water, the canals in the vicinity must be maintained and kept full.

In this county, as a rule, the cereals are not irrigated, and between the San Joaquin and Kings rivers there are probably 75,000 acres of land not needing irrigation. For the best development of the fruits, however, artificial application of water is essential. Some of the land otherwise good is worthless from the presence of an excess of alkali, and other lands are doubtless being injured by the accumulation of earthy salts, due to lack of suitable drainage. Irrigation must be accompanied by drainage in order to accomplish the best results. The development of the county has been greatly retarded by litigation over questions of riparian rights, land owners along the lower course of Kings river having secured injunctions against the largest irrigating canals. During the census year water was run in these canals in spite of the injunctions, public sentiment being so strong in condemnation of the decisions that the injunctions could not be enforced. The returns from land irrigated and set to raisin grapes are stated to be from $50 to $250 per acre, while those from land unirrigated and devoted to grain may be $5 an acre or less. The colony lots of from 10 to 20 acres, when covered with bearing vines, are considered to be amply sufficient for the support of a family. The great returns in the grape and fruit business and the large amount of labor involved have led to the cutting up of large ranches and the formation of colonies.

The water supply is derived mainly from Kings river, on the southern border of the county, and from the San Joaquin, which flows about through the center. Besides these are a number of smaller rivers or creeks, the most important being Fresno river and Chowchilla creek, both north of San Joaquin river. Chowchilla creek, which forms a portion of the northern boundary of the county, was measured by the state engineering department at a point near Buchanan, where a record of the height of water was kept at intervals. This stream is characterized by short, sudden freshets, making it exceedingly difficult to estimate the discharge. The monthly averages, as computed, are given in a short table in the description of Merced county.

Fresno creek, or river as it is sometimes called, was measured at the head of the Fresno River Canal and Irrigation Company's canal, about 3 miles above the railroad crossing near Minturn. The mean monthly discharge is shown in the following table:

DISCHARGE IN SECOND-FEET OF FRESNO CREEK AT BASE OF FOOTHILLS, CALIFORNIA.

(Drainage area, 272 square miles.)

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1879	27	80	118	156	79	15	0	0	0	0	0	109	49
1880	5	150	16	1,088	54	27	0	0	0	0	0	218	130
1881	544	544	272	109	54	....	0	0	0	0	0	27	129
1882	54	163	1,088	272	54	0	0	0	0	27	54	27	138
1883	82	54	272	136	109	0	0	0	0	0	0	0	54
1884	27	1,360	1,632	1,088	816	816	272	27	0	0	0	0	....

The San Joaquin river where it enters the valley from the mountain region on the northeast is among the largest of the streams crossing the broad plains. Observations were made at a number of points, mainly at Hamptonville, at the edge of the valley, and at the railroad crossing near Herndon, formerly Sycamore. At that time little or no water was diverted at points above the railroad. The mean discharges as computed by the state engineer are given in the table on the following page.

DISCHARGE IN SECOND-FEET OF SAN JOAQUIN RIVER AT HAMPTONVILLE, CALIFORNIA.

(Drainage area, 1,637 square miles.)

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1879	609	1,276	1,953	3,849	5,302	6,379	2,303	786	381	373	411	1,140	2,064
1880	825	942	1,229	4,846	13,170	18,120	8,010	1,730	734	422	380	2,001	4,367
1881	3,856	6,340	2,855	8,008	9,095	5,948	3,064	1,260	584	463	461	632	3,547
1882	303	330	1,522	3,400	8,850	7,867	2,918	591	240	564	490	320	2,292
1883	320	320	1,150	2,130	7,370	6,220	1,470	490	410	330	250	250	1,726
1884	410	2,460	4,090	3,270	8,190	16,400	13,100	3,270	980	820	....	....	....

Kings river is one of the most important streams of this part of the state, since it receives a large and constant supply of water from its elevated catchment area. The gaugings made by the state engineer were at localities between Slate point, where the river leaves the mountains, and Tulare lake. The record of the height of the stream was kept at the railroad bridge near Kingsburg, and from these observations the discharge was computed, due allowance being made for the amount of water diverted by canals heading higher up stream. The results are shown in part in the following table.

DISCHARGE IN SECOND-FEET OF KINGS RIVER AT SLATE POINT, CALIFORNIA.

(Drainage area, 1,742 square miles.)

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1879	370	870	1,970	4,750	5,090	3,760	1,650	380	270	280	400	1,440	1,770
1880	720	1,040	1,120	5,230	7,120	9,540	4,800	1,150	370	220	220	510	2,670
1881	870	2,430	1,900	5,800	8,220	5,010	4,790	650	340	250	230	260	2,563
1882	380	440	1,250	3,170	9,190	6,410	2,020	620	390	610	470	340	2,108
1883	320	340	1,050	2,220	6,700	6,730	1,460	600	480	420	260	260	1,737
1884	430	2,620	3,610	3,370	9,210	17,630	13,210	3,570	880	900	....	....	....

There are a number of flowing wells on the low grounds near the lower end of Chowchilla creek and in Fresno slough. The total number enumerated upon farms in 1890 was 47, the depth ranging from 72 to 1,200 feet, the average being 562 feet. As a rule, little if any of the water is used for irrigation. At Kingsburg, east of the artesian area, a well was bored to the depth of 600 feet, but without success. Also at Madera, 20 miles northwesterly from Fresno, a well was put down to the depth of 1,200 feet, but the water does not rise to the surface. It is necessary to employ windmills in this vicinity in order to raise water for stock.

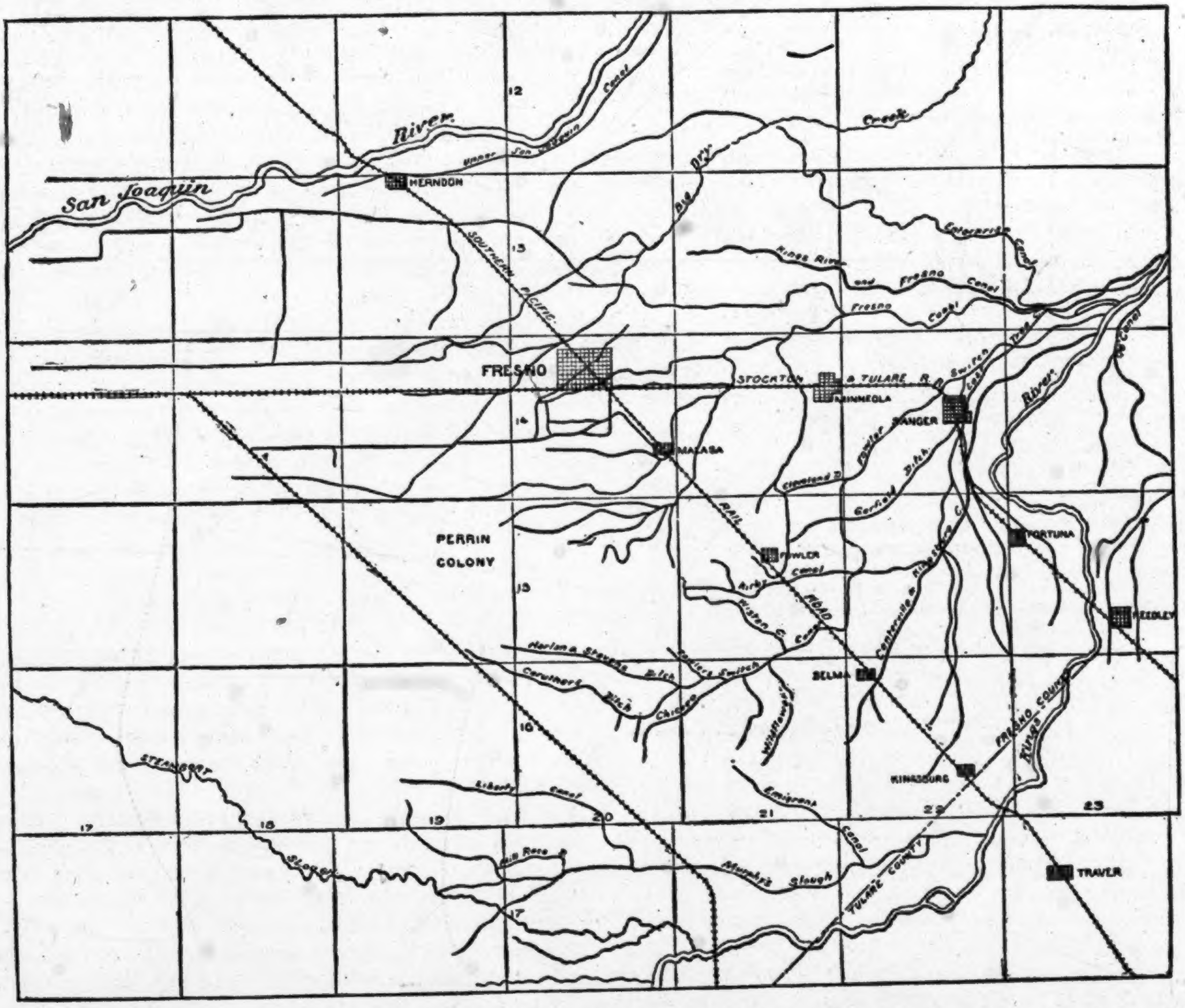
There are at least 16 important irrigation systems taking water from Kings, San Joaquin, Fresno, and other rivers and covering over a half million acres of land. The total length of the principal canals is stated to be upward of 750 miles, and there are doubtless over a thousand miles of distributing ditches. There are stated to be 12 dams across the rivers, as well as other works for diverting the water. The total cost of all these systems has been placed at about $2,000,000. The farming land under these canals has an assessed value of from $25 to $40 per acre, and sells readily at from $50 to $100 per acre. The unirrigated lands are assessed at from $5 to $10 per acre, and sell probably at from $10 to $20 per acre. Of the land irrigated, it is estimated that from 1 to 2 per cent is in fruit, 15 to 20 per cent in grapes, about 10 per cent in alfalfa, and the balance in cereals, the value of the fruit and grape product being far greater than that of all other crops put together. While not attempting to give a detailed description of each irrigating system, it may not be out of place to mention a few of the typical canals.

Among the canals taking water from Kings river in this county are the Enterprise, Kings River and Fresno, Fresno, Fowler Switch, Centerville and Kingsburg, Emigrant, and Liberty. From the San Joaquin are the Upper San Joaquin and other canals heading in the foothills, and lower down is the San Joaquin and Kings River canal, taking water out on the west side of the valley in the vicinity and north of Firebaugh and extending to and beyond Los Banos in Merced county, as shown on the map of the vicinity of Merced. Also on the east side of the river are the Chowchilla and other canals covering the lowlands. Other canals, as, for example, Madera and Fresno River, head along Fresno river and Dry and Chowchilla creeks in the northern part of the county.

The Enterprise canal takes water from the west side of Kings river and carries it out in a northwesterly course along the upper edge of the valley land toward the point where the San Joaquin river leaves the mountains. The total length is about 30 miles, the average width 20 feet, and the cost was approximately $40,000. Work on the canal was begun in 1885 and water was first used in 1886. From the river water is diverted by means of a wing dam made of cobblestones, replaced whenever the river falls and fails to supply the canal. Lands can be brought under irrigation within 4 miles of the headworks. There are few deep cuttings along the line and only

5 flumes. The canal is owned by a corporation, 6 shares in which entitle the holder to 1 second-foot of water, an amount considered sufficient to irrigate 160 acres. The cost of the water right was about $5 per acre, and the annual assessment is about 65 cents per acre. Water is used mainly for irrigating vineyards, which are moistened two or three times during the year, beginning in March and ending in July.

MAP OF IRRIGATING CANALS IN THE VICINITY OF FRESNO, FRESNO COUNTY, CALIFORNIA.


12
San Joaquin River
Upper San Joaquin Canal
HERNDON
Big Dry Creek
Enterprise Canal
Kings River and Fresno Canal
Fresno Canal
13
SOUTHERN PACIFIC RAIL ROAD
FRESNO
STOCKTON & TULARE R. R.
MINNEOLA
SANGER
Swifton Last Tree
River
Canal
14
MALAGA
Fowler Ditch
Cleveland D.
Garfield Ditch
FORTUNA
PERRIN
COLONY
15
FOWLER
Canal
Kirby
Wisten C.
Centerville & Kingsburg C.
REEDLEY
Harlan & Stevens Ditch
Caruthers Ditch
Chicago
Fowlers Switch
Wildflower
SELMA
16
FRESNO COUNTY
Kings
KINGSBURG
Liberty Canal
Emigrant Canal
STEAMBOAT SLOUGH
17
18
19
20
21
22
23
Rio Rosa
17
Murphy's Slough
TULARE COUNTY
TRAVER

The Kings river and Fresno canal, sometimes known as the Gould canal, is the next in order below the Enterprise, and carries water to lands north and east of Fresno. The total length of the main ditch is 22 miles, the average width 24 feet, and the capacity is estimated to be from 250 to 300 second-feet when full. The cost is stated to have been $100,000. The canal was begun in 1871, used in the following year, and enlarged in 1881. Under this canal, as in the case of that described above, 1 second-foot is supposed to irrigate 160 acres. The amount of water flowing in a box 18 inches wide and having a depth of 4 inches, without head or back pressure, is supposed to be 1 second-foot, although as a matter of fact the quantity must vary greatly. Also the quantity of water flowing through an opening 1 inch in height and 50 inches in width under a 4-inch pressure has been defined as being a second-foot. Shares are valued at $100, each entitling the holder to one-fourth of a second-foot of water, and the annual assessment is about 50 cents per acre.

The irrigating system belonging to the Fresno Canal and Irrigation Company, commonly known as the Church or Perrin canal, takes water from the west side of Kings river, the head works being about 20 miles east of Fresno. The total length of the main ditches is about 200 miles, the width being from 100 feet down to 10. The ordinary discharge of the main canal is estimated to be about 1,000 second-feet. The total cost of the canal and system of ditches was probably $1,000,000. The canal was begun in 1868 and the distributaries are still being extended. Water is diverted by means of a small stone dam, and there are no works of engineering importance, such as flumes or deep excavations, along its line. Besides the main ditches, there are several hundred miles of distributaries, covering an area 40 miles in length from east to west and about 15 miles in width. It is customary to estimate that 1 second-foot will irrigate a quarter section, or 160 acres. No attempt is made to measure the exact quantity, but persons owning water rights in general use as much water as they desire.

This canal system is owned by a corporation, but the shares do not entitle the holder to the use of water, the water rights being sold entirely independent of ownership in the canal. The cost of water right per acre is stated to be $6.25, or $1,000 per quarter section. The annual assessment is 62.5 cents per acre. The most important product is raisin grapes. Second in value to these are the grapes raised for wine, the fruits, vegetables, and alfalfa. In this vicinity, as in many localities in the state, it has been found that the amount of water required for irrigating an acre depends upon the length of time during which the land has been under irrigation. When water is first applied it is necessary to use from 2 to 3 second-feet for each quarter section, but in the course of a few years the land becomes saturated, or, as it is commonly called, "subirrigated", requiring far less water. Many of the older irrigators do not use water directly, but depend entirely upon subirrigation. When irrigation was first introduced it is stated that in many localities water could be found only at depths of 100 feet. In the same localities at the present time water can be found at depths of from 5 to 15 feet. Improved lands under irrigation now yield products valued at from $50 to $200 per acre, while the unimproved land is worth from $75 to $100 per acre.

The Fowler Switch canal is below that of the Fresno Canal and Irrigation Company and covers land in the vicinity of Fowler, 8 miles southwesterly from Fresno. The total length of the main canal is about 30 miles, width 40 feet, and the cost was in round numbers $300,000. It was begun in 1882 and used in 1884. The canal was owned by a corporation, 300 shares at $1,000 each being issued. The water has been rented at $32 per share. This canal as well as others has suffered from the enforcement of the so-called riparian laws. In the case of this irrigating system and others adjoining some water is supplied to canal companies or associations owning the branch lines.

The Centerville and Kingsburg canal also takes water from the west side of the Kings river, but for a large portion of its course follows along within only 2 miles of the river. The total length of the main ditch is about 22 miles, the average width 30 feet, and the cost was approximately $100,000. The canal was begun probably in 1877. There are 3 main branches each about 20 feet in width, as well as a large number of smaller ditches.

The Madera canal takes water from Fresno river, carrying it out on the south side in a southwesterly direction. The total length of the main canal is 40 miles, the average width 15 feet, and the total cost was $160,000. Water rights have been sold at $5 per acre, the annual assessment being $1 per acre. Water is used mainly for raisin grapes, fruit, alfalfa, and some small grain. No attempt is made to measure the water, but the annual charges are made according to the acreage. There is great variation in the land, some being heavy and not requiring one-half as much water as do the adjoining tracts of light sandy soil.

HUMBOLDT COUNTY is one of the northern coast counties, lying in a relatively narrow strip along the Pacific ocean and separated from Oregon by Del Norte county. The greater part of the area is mountainous and heavily timbered, and the larger rivers flow through deep, narrow valleys. The rainfall is heavy and is sufficient for the needs of agriculture, irrigation being exceptional. The few irrigated areas reported consist mainly of orchards, vegetable gardens, and fields of alfalfa, to which water has been brought for use during the late summer droughts. The ditches are small, costing probably not more than $50 or $100, and taking water from some spring or rivulet to cultivated patches near by. In this part of the state several deep borings have been made for the purpose of obtaining water supply. One of these was near the town of Eureka, while other attempts to strike flowing water have been made in the reclaimed salt marshes near Ferndale.

INYO COUNTY lies on the eastern side of the Sierra Nevada range and adjoins Esmeralda and Nye counties, Nevada, to which it is similar in climate and topography, being within the great interior basin. On the extreme western edge of the county are the high peaks of the Sierras, rising to altitudes of 14,000 feet and upward and covered throughout the year with snow. From these come numerous streams, which, descending rapidly, unite to form Owens river, flowing southerly along the base of the range to Owens lake. Along each side of Owens river is a strip of agricultural land, but upon which crops can be raised only by irrigation. To the east of this is a succession of ranges and deep valleys of what is known as the Great Basin type, similar to those in southern Nevada. In these valleys the water supply is so limited that agriculture is impossible, except at a few restricted localities in the vicinity of springs or of the small perennial streams. The most noted among these lowlands between the mountains is Death valley, the bottom of which is reported to be upward of 350 feet below sea level. Borax and similar substances are obtained in these depressions, but beyond these products the desert area has little present value.

The streams which enter Owens valley from the west are diverted by numerous ditches, and there are also several canals already in use or under construction deriving their supply from Owens river and covering both sides of the valley. The principal among these is the Inyo canal, heading about 6 miles above Independence and carrying water out on the east side of the valley as far south as Owens lake. This ditch is reported to be 50 feet in width near the head, 30 miles in length, and to have a capacity of 300 second-feet. Besides this ditch there are on the east side of the river the McNally, Zeiger, and Collins, in the northern end of the valley, and on the west side the Stevens ditch, heading near Independence. A large irrigating system known as the Owens river canal has been projected to cover the entire west side of the valley, the head being 10 miles west of Bishop station, and the main canal extending down to and even beyond Owens lake.

The Bishop creek ditch heads on the south side of Owens river, about 6 miles west of Bishop station. It is 14 miles long, from 16 to 20 feet in width, and has cost over $15,000. It is owned by a corporation composed of farmers, each share in the ditch entitling the owner to 0.5 second-foot of water. Each share cost from $250 to $500. There is apparently an ample water supply for the land now under irrigation, but it is probable that it will be necessary to resort to water storage in the future at localities known to be favorable.

KERN COUNTY is in the extreme southern end of San Joaquin valley, extending from the coast range easterly across the end of the valley to and beyond the Sierra Nevada mountains, and including in its southeastern corner a portion of the Mohave desert, a part of the great interior basin of western United States. The most valuable lands of the county are those which lie within the San Joaquin basin between the lowest ground and the foothills of the Sierra Nevadas. The rivers which come from the high mountains forming the southern end of the Sierra Nevadas discharge their waters out upon the nearly level plain at the southern end of the San Joaquin valley, the fall near the center being so slight that the channels are not well defined, and the water for a great part of the year flows sluggishly through what are known as sloughs and forms in places large marshes or open lakes. There were formerly two lakes of considerable size in this county, Buena Vista and Kern, the river discharging into Kern lake, then westerly into Buena Vista, the excess water of which flowed out northerly into the sloughs extending to Tulare lake. Works of river reclamation and improvement have, however, changed the condition of things so that Kern lake has disappeared and Buena Vista, confined within narrower limits, serves as a reservoir for lands to the north.

The greater part of the agricultural lands of this county are under the control of two large corporations or associations of capitalists. The first of these, the Kern County Land Company, owns the lands formerly known as the Haggin and Carr property, while the second, the San Joaquin and Kings River Canal and Irrigation Company, or Miller and Lux, controls the lands northerly from Buena Vista reservoir. There has been a long legal warfare between these companies over the use of the water of Kern river, the matter being finally settled by agreement, all parties joining in works of river improvement and water storage in Buena Vista lake. Until within a few years nearly all of the lands held by these great owners were utilized, if at all, for pasturage and for raising forage crops and the cereals, tracts of several thousand acres being flooded in a wholesale manner by means of checks or low levees a few inches in height constructed on contours. In the latter part of the last decade the owners began to see the advantages of cutting up these great holdings into small lots and selling these to colonists who would set them out in fruit, it being found that the climate was favorable for the profitable production of all the fruits for which California is famous.

A number of colonies have been started in the vicinity of Bakersfield and at other points, mainly on the eastern side of the valley, and lands which formerly yielded under irrigation only forage and grain are now set out to the most expensive orchards and vineyards. Much of this land requires but little water, one good wetting a year being sufficient. In some cases no direct irrigation is practiced, but the seepage from canals at a distance suffices to keep the ground sufficiently moist. In wet years the small grains can be raised usually without any application of water even on lands above the canals. Although large areas have been subdivided, there still remain a number of great ranches, devoted mainly to the raising of horses and cattle.

This county is noted for the number of artesian wells and the large quantity of water discharged by them. The principal wells, as shown on the map, are found in the region of country lying from 10 to 20 miles west of the Southern Pacific railroad and between it and that part of Kern river known as Buena Vista slough and Goose Lake slough, being in the vicinity of the Smyrna, Miramonte, and other colonies. They are thus located mainly within townships 25, 26, and 27 south, ranges 22, 23, and 24 east, Mount Diablo meridian. There are also many flowing wells in the lower part of what is known as the Kern delta, south and west of Bakersfield. It is claimed that the largest wells are in township 23 east, range 27 south, this being about 40 miles southerly from Tulare lake. In this township the Kern County Land Company had in the census year 24 artesian wells, of from 300 to 1,100 feet in depth, and also 4 wells not flowing, of from 400 to 1,000 feet in depth. The discharge ranged from 40 to 420 gallons per minute, or from 0.1 to 1 second-foot. A few wells were reported as discharging as high as 4 second-feet, or approximately 2,500,000 gallons per day. Comparatively little of this water has yet been used for irrigation, but it is probable that it will be more fully utilized as the colonies increase. The cost of these wells varied from $2 to $3 per foot in depth.

As an example of the largest wells may be given one in section 17, township 26 south, range 23 east. This is 635 feet deep, 8 inches in diameter, and cost $1,875. It discharges at the rate of 3.7 second-feet, and has irrigated 320 acres. This area was covered by young orchards of plum and fig trees, by raisin vines, grain for hay, alfalfa, corn, sorghum, vegetables, and shade trees. Taking Kern county as a whole, the average depth of the wells is 551 feet, diameter 8 inches, and cost $1,489. The discharge is 1,072 gallons per minute, and the average area irrigated by each well used for that purpose was 125 acres.

VIEW OF KERN RIVER AND CANAL ON SOUTH SIDE ABOVE BAKERSFIELD, KERN COUNTY, CALIFORNIA.

The larger canals of the county depend upon the Kern river, which, rising in the lofty Sierra Nevadas, flows southerly and then southeasterly into the head of the San Joaquin valley. To the south and north of this are other streams having a less area of mountain catchment and a far smaller discharge. The quantity of water flowing in these streams was measured by the state engineering department of California and the results were published in the "Physical Data and Statistics of California", already cited. The Kern river was gauged chiefly at the Rio Bravo Ranch station, a point below the mountain canyon and above all canals of diversion in the valley. Readings of the height of water were kept from 1878 to 1883, these data forming the basis for computing the discharge.

DISCHARGE IN SECOND-FEET OF KERN RIVER AT RIO BRAVO RANCH, CALIFORNIA.

(Drainage area, 2,345 square miles.)

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1879	462	591	552	764	927	971	535	268	171	182	261	356	503
1880	354	370	389	1,557	2,650	3,317	2,196	1,060	767	758	767	1,063	1,280
1881	1,078	1,773	1,570	2,288	2,362	1,890	1,126	627	361	333	337	350	1,183
1882	335	395	600	1,174	1,670	1,306	726	330	330	330	280	280	646
1883	280	350	700	1,170	1,410	1,170	940	470	350	280	200	200	627
1884	350	470	940	1,980	5,860	9,380	5,860	2,350	940	470	....	....	....

The mean discharge of Caliente creek, lying to the south of Kern river, has been computed by the state engineer of California from considerations of the rainfall and of the probable drainage per square mile. The results are considered as approximate only, but as such have their value, and are therefore given in the following table:

DISCHARGE IN SECOND-FEET OF CALIENTE CREEK AT BASE OF FOOTHILLS, CALIFORNIA.

(Drainage area, 423 square miles.)

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1879	34	59	30	106	76	25	0	0	0	0	110	212	54
1880	508	973	1,100	1,227	846	212	21	0	0	0	85	212	432
1881	212	423	423	423	423	212	0	0	0	0	0	51	181
1882	51	63	212	212	42	0	0	0	0	0	63	63	59
1883	63	63	338	212	169	0	0	0	0	42	42	63	83
1884	212	1,269	1,269	846	169	212	0	0	0	0	....	....	....

Poso creek drains the area to the north of Kern river, entering the valley east of Goose lake. Here, as in the case of Caliente creek, the computations of discharge have been based upon considerations of rainfall and drainage. The following table gives therefore the best information available:

DISCHARGE IN SECOND-FEET OF POSO CREEK AT BASE OF FOOTHILLS, CALIFORNIA.

(Drainage area, 289 square miles.)

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1879	23	40	20	72	52	17	0	0	0	0	75	145	37
1880	347	665	751	838	578	145	14	0	0	0	58	145	295
1881	145	289	289	289	289	145	0	0	0	0	0	35	123
1882	35	43	145	145	29	0	0	0	0	0	43	14	38
1853	43	43	231	145	119	0	0	0	0	29	29	43	57
1884	145	867	867	578	119	145	0	0	0	0	....	....	....

Measurements of the amount of evaporation from exposed surface of water were made at various points in Kern county and also at Kingsburg, in Tulare county, by the state engineering department of California in 1879 and later years. Those in Kern county were commenced in June, 1879, and were carried on during July, August, and September, the hottest months of the year, being supplemented by observations made into December at Rio Bravo ranch, about 10 miles east of Bakersfield. The Kern county measurements were made from pans of galvanized iron 2 feet square and 1 foot deep, some of these being floated in large bodies of water, and in other cases the pans were set in open ground.

The following statement shows the average evaporation in inches per 24 hours, as obtained at the different localities:

	INCHES.
Reeder lake, a narrow body of water 12 to 15 feet deep, surrounded by large cottonwood trees and willows. Pan placed in a shallow arm of the lake, fully exposed to the sun, but protected from the wind. June 25 to July 8	0.24
Panama slough. Pan placed in running water 10 feet deep, having lower temperature than Reeder lake; fully exposed to sun, but protected from the wind. July 9 to August 20	0.14
Kern lake, about 2 miles from shore. Pan in 5 feet of water. September 5 to 29	0.22
Kern lake, near shore. Pan in 2 feet of water. August 30 to September 29	0.32
Kern river, at Rio Bravo ranch, 3 miles below the mouth of Kern river canyon. Pan freely exposed to sun and wind, but immersed in water to within 2 inches of its top:	
October 11 to 25	0.11
November 1 to 29	0.09
December 6 to 20	0.05

At the same time a pan was kept on top of the ground, free to the action of the weather, resulting in greater evaporation. The results of all of these measurements are shown in a different form in the following table, the mean daily evaporation in each case being multiplied by the number of days in each month. In doing this a number of assumptions are made, some of which may be questionable, but the results obtained afford a basis for judging of the possible monthly evaporation. At the bottom of the table are given figures showing in inches the computed evaporation at Fresno, in Fresno county, these representing possibilities of evaporation rather than actual loss. Below these are given the percentages showing the relative evaporation in each month of the year.

COMPUTED DEPTH OF EVAPORATION, MONTHLY.

STATIONS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total for year.
Reeder lake						7.5							
Panama slough							4.4	4.5					
Kern lake, center									6.5				
Kern lake, northeast shore									9.5				
Kern river										3.5	2.0		
Rio Bravo ranch (ground)										7.6	3.7	1.6	
Fresno (a) inches	1.8	2.8	3.0	5.6	6.6	7.0	9.1	10.2	7.6	6.7	3.8	2.2	65.8
Fresno per cent	2.7	4.3	4.6	8.5	9.1	10.6	13.9	15.5	11.5	10.2	5.8	3.3	100.0

a Depth of evaporation in the United States. T. Russell. (Extract from Monthly Weather Review, September, 1888.)

The principal canals of the county are owned or controlled by the Kern County Canal and Water Company, which is under the same management as the Kern County Land Company, the property being known as the Haggin and Carr lands. A general description of their works, as given by Walter James, chief engineer, is as follows:

> All of the canals take their water from Kern river, the discharge of which has been discussed on a previous page. The average flow of the river during June and July is assumed to be about 3,500 second-feet. In 1884 and 1890 it was probably about 7,000 second-feet, these being regarded, however, as exceptional years. From August 1 until November 1, during which period but little water is needed for irrigation, the discharge may be as low as 300 second-feet, the average being about 500 second-feet. During the time of winter rains, that is, from November to March, the discharge is about 1,000 second-feet.

During periods of high water the excess over the amount required by the various canals flows down the channel southwesterly from Bakersfield to a point north of Buena Vista lake and is there deflected by dikes southerly through the inlet canal, which is 400 feet in width, into the lake, as shown on the map. This lake, which has been converted by means of levees into a reservoir, thus holds the flood waters, which are used later in the season upon the lands to the northward extending to Tulare lake, these lands having a less altitude. The total area of this reservoir is about 25,000 acres. The evaporation from its surface has been discussed in part on a preceding page.

CANALS ON NORTH SIDE OF KERN RIVER.

NAMES OF CANALS.	Located—	Length in miles.	APPROPRIATION.		Bottom width in feet.	Slope of banks.	Depth of water in feet.	Fall in feet per mile.	CAPACITY IN SECOND-FEET BY KUTTER'S FORMULA. VALUES OF N.		
			Miner's inches.	Second-feet.					0.025	0.030	0.035
Beardsley (a)	Dec. 2, 1873	8.0	47,230	938	40	3 to 1	4.0	1.0	371	307	263
McCord	Mar. 20, 1875	14.5	5,000	100	30	3 to 1	3.0	1.5	207	171	146
Calloway (a)	May 4, 1875	32.0	74,000	1,476	80	3 to 1	5.0	0.8	921	776	656
McCaffrey	Oct. 31, 1874	3.0	1,296	26	10	1 to 1	2.0	1.5	30	24	20
Emery	Dec. 2, 1876	2.0	2,000	40	6	3 to 1	2.0	1.5	27	22	18
Jones and Tuckey	June 24, 1876	4.0	1,000	20	4	3 to 1	2.0	1.5	21	17	14
Railroad	July 24, 1874	0.6	31,075	620	40	3 to 1	3.0	2.0	309	256	216
Wible	May 1, 1875	0.2	5,040	100	40	3 to 1	3.0	2.0	309	256	216
Goose Lake (a)	July 13, 1875	4.5	90,000	1,795	140	3 to 1	3.0	2.0	1,024	850	727
Pioneer	Apr. 26, 1873	11.5	20,074	400	40	3 to 1	3.0	2.0	309	256	216
Edwards	Dec. 21, 1874	2.0	1,440	29	6	1 to 1	1.0	1.5	7	6	5
James and Dixon (a)	Apr. 29, 1873	3.0	14,000	279	40	3 to 1	3.0	2.0	309	256	216
Johnson	June 12, 1873	4.0	8,640	172	30	3 to 1	3.0	1.5	207	171	146
Ashe (b)	....	1.0	1,200	24	....	....	....	....	....	....	....
May (b)	Nov. 29, 1873	2.0	4,000	80	....	....	....	....	....	....	....
Joice (a)	June 2, 1873	4.0	6,250	125	10	3 to 1	2.0	2.0	44	36	31

CANALS ON SOUTH SIDE OF KERN RIVER.

NAMES OF CANALS.	Located—	Length in miles.	Miner's inches.	Second-feet.	Bottom width in feet.	Slope of banks.	Depth of water in feet.	Fall in feet per mile.	0.025	0.030	0.035
Kern Island (a)	1870	30.0	20,000	400	40	3 to 1	4.0	2.0	503	427	373
Old South Fork	....	3.0	3,800	75	20	1 to 1	2.0	5.0	112	92	78
Farmers	Apr. 20, 1873	19.7	14,400	287	30	2 to 1	3.0	2.0	233	193	164
Castro	....	5.0	1,000	20	16	1 to 1	1.5	2.0	35	28	24
Stine (a)	Dec. 12, 1872	47.5	55,980	1,117	30	3 to 1	3.0	2.0	241	198	169
Anderson (a)	Oct. 9, 1872	4.0	5,057	101	20	1 to 1	2.0	1.5	61	50	42
Gates (a)	Oct. 7, 1872	2.5	5,057	101	12	3 to 1	2.0	1.5	44	36	30
Buena Vista (a)	July 15, 1870	13.2	14,000	279	30	3 to 1	3.0	2.0	241	198	169
James (a)	Oct. 15, 1871	17.2	19,730	394	40	3 to 1	3.0	2.0	309	256	216
Plunket (a)	Dec. 31, 1872	3.7	5,057	101	12	3 to 1	2.0	1.5	44	36	30
Meacham (a)	Apr. 15, 1873	4.0	1,500	30	12	3 to 1	2.0	1.5	44	36	30
Wilson	Aug. 15, 1874	2.5	500	10	4	3 to 1	2.0	1.5	21	17	14
Henley (b)	Jan. 29, 1874	2.5	2,880	57	....	....	....	....	....	....	....
Frazer (b)	Apr. 15, 1873	2.2	2,600	52	....	....	....	....	....	....	....
Kern Valley Water Company (a)	Apr. 7, 1877	40.0	130,000	2,594	125	3 to 1	10.0	0.9	5,026	4,238	3,722

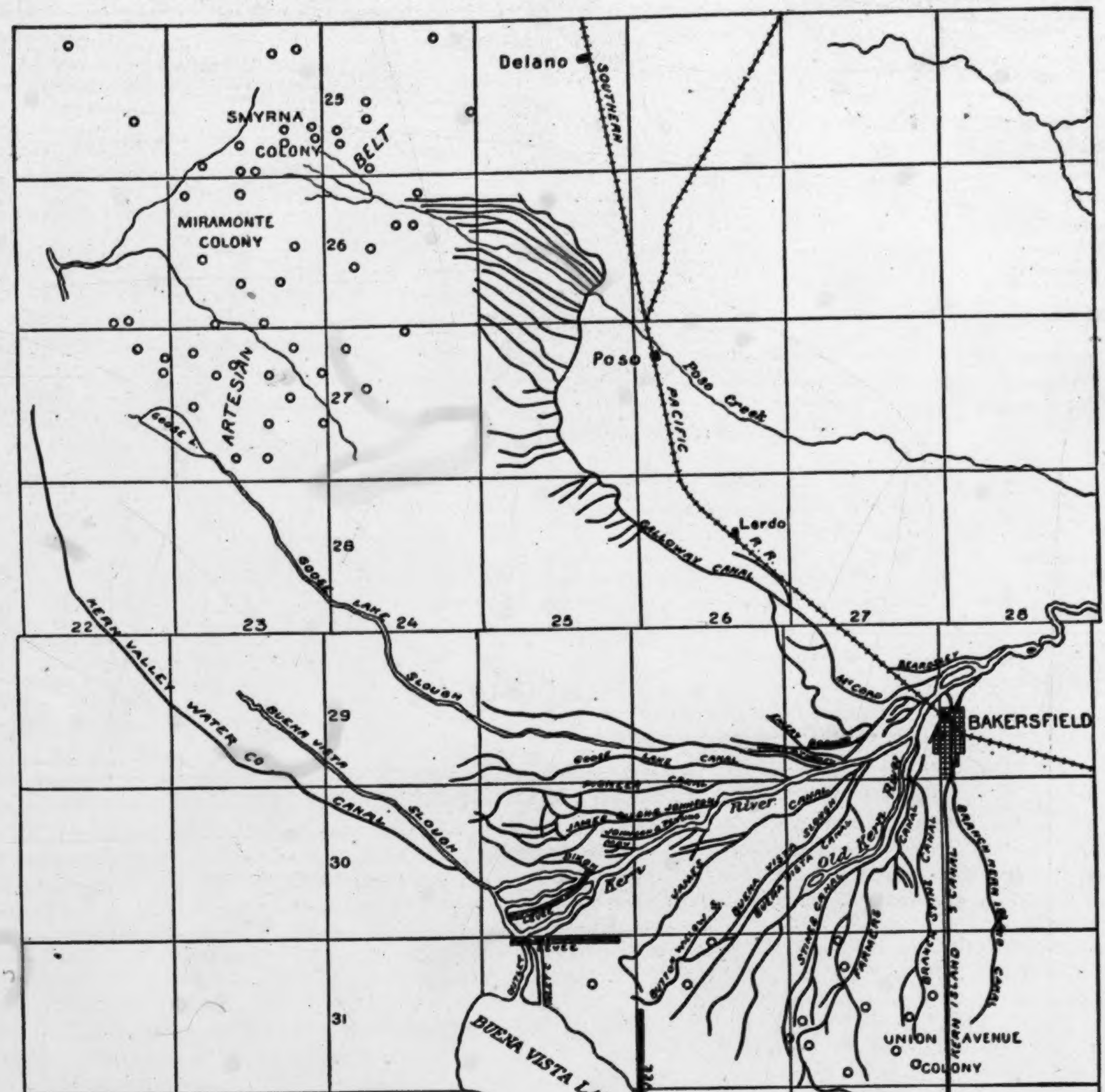
a Canals owned by incorporated companies. b Abandoned canals.

The Railroad, Wible, and Goose Lake canals discharge into a natural channel called Goose Lake slough, which, as shown by the map, runs to Goose lake, the water being taken out at various points along this channel and used by the owners of shares in these 3 canals. All of these canals were completed to their present length within 3 years of the date of their location. As they are cleaned out, however, the banks are being made higher and their capacity increased to meet the requirements of the lands brought under irrigation each year. All of the canals are carried through a nearly flat country where there is no rock or expensive excavations, the cuttings not exceeding 3 feet in depth. Several of the canals, as, for example, the Beardsley, Calloway, and McCord, after leaving the river, follow as nearly on contour lines as is possible with cuttings of from 2 to 3 feet.

At the head of the Beardsley canal is a weir 60 feet long, extending to an island in the river. Also at the head of the McCord canal is a similar structure. The head works of the Kern Island canal are provided with a wing dam built of sand and brush, and requiring repairs in every change of the stage of water. A wasteway at the head gate serves to some extent to save this dam. The South Fork canal, which has its head near that of the Kern Island canal, occupies in common with the Farmers canal a natural channel. At the heads of the Farmers and Calloway canals, which take out water on opposite sides of the river, is a weir extending completely across the channel and having a length of 400 feet. It is notable from the fact that it is built upon piles driven into the sandy channel, and, though constructed in the lightest and most simple fashion, has for several years withstood the attacks of heavy floods.

At the head of the Buena Vista and James canals there is a weir in the river 300 feet long, and at the head of the Pioneer, Meacham, Wilson, Goose Lake, Wible, and Railroad canals there is a weir 360 feet long crossing the river. At the head of the Johnson and James and Dixon canals is a weir 200 feet long, and at the head of the Joice canal is a weir 280 feet long. Water is diverted to all of the other canals by means of temporary wing dams. From the canals the water is taken through side gates, weirs being necessary to regulate the fall in the canals and the flow of water through these side gates. The quantity of water in the canal is estimated by measurements over the weirs. On none of these canals excepting the Kern Island, Stine, Beardsley, and Calloway is the water measured to the consumers. In the case of the first two of these the quantity is measured in miner's inches under a 4-inch pressure and charged for at the rate of 75 cents per second-foot for 24 hours. On the Beardsley and Calloway the water is measured through submerged openings, the charges being at the rate of $2.16 per second-foot for 24 hours. It is estimated that 1 second-foot will irrigate in 24 hours 10 acres of orchards or vines or 1 acre of grass or grain.

MAP OF IRRIGATING CANALS IN THE VICINITY OF BAKERSFIELD, KERN COUNTY, CALIFORNIA.


Delano
SOUTHERN
PACIFIC
R. R.
SMYRNA COLONY
BELT
MIRAMONTE COLONY
ARTESIAN
Goose L.
Poso
Poso Creek
Lerdo
Calloway Canal
25
26
27
28
29
30
31
32
22
23
24
Goose Lake Slough
Kern Valley Water Co Canal
Buena Vista Slough
Beardsley
McCord
BAKERSFIELD
Goose Lake Canal
Pioneer Canal
James
River Canal
Kern
Old Kern River
Buena Vista Slough
Buena Vista Canal
Stine's Canal
Farmers
Canal
Branch Stine Canal
Kern Island Canal
Branch Kern Island Canal
Buena Vista Lake
Levee
Outlet
Inlet
UNION AVENUE COLONY

In addition to the water supply obtained from the canals there are in this county several pumping plants by which water is raised to a height of from 10 to 30 feet, and at a cost not greater than that just given above. Besides these there are, as previously described, many artesian wells, furnishing considerable quantities of water. It is estimated by Mr. James that from all sources of supply an area of from 500,000 to 600,000 acres may be irrigated, all of this being under the canals above mentioned. In the case of each of these canals the water is distributed to shareholders according to the number of shares owned by each, except at times when the water is in excess of demands, when each owner receives as much as he wishes. The canals are usually cleaned in the fall at the times when water is not needed, but are sometimes allowed to run uncleaned for two or three years.

The lands under irrigation in this county, as stated by Mr. James, in a state of nature, would produce feed for stock in quantity to the value of, say, 10 cents an acre per year. In other words, a stock raiser could not afford to pay as rental more than 10 cents per acre, for the land in its natural condition in this portion of the San Joaquin valley is of little use for other purposes than grazing.

Besides the canals taking water from the Kern river and other streams in the lower end of the San Joaquin valley, there are a number of small ditches deriving a supply from the tributaries of the Kern river and irrigating small areas in the mountain valleys. Among these may be mentioned those in the vicinity of Havilah in Hot Spring valley and in the vicinity of Kernville and Weldon. In the southern part of the county, also, south of the Tehachapi pass, are small irrigating systems and others projected or under construction. The principal ones of these have in view the reclamation of lands in Antelope valley, the greater part of which is in the northern end of Los Angeles county. On Oak creek, 10 miles southwest from Mohave, it has been proposed to irrigate lands by means of water from a reservoir supplied by Oak creek and its numerous springs. Under present conditions the settlers are too poor and too widely scattered to accomplish much, and the land, though highly fertile under irrigation, is naturally of such a desert character that the pioneers barely make a living.

Lake county is one of the smaller interior counties lying within the coast range of mountains. The nearest part of the county is about 60 miles north of San Francisco, and from this point it extends northerly for approximately the same distance. The most conspicuous topographic feature of the county, and the one from which it receives its name, is the large lake near its center. This, known as Clear lake, drains easterly and southerly by means of Cache creek through Capay valley, Yolo county, to the Sacramento. Around the shores of the lake are several valleys in which agriculture is carried on. Irrigation is practiced to a relatively small extent, principally for vegetable gardens, trees, and alfalfa. For general farming purposes the annual rainfall is sufficient. The water supply of the county as a whole is large, although during the latter part of the summer the tributaries to Clear lake dwindle and become almost if not quite dry. In a few instances water is pumped from the lake by means of horse power and used in truck farming, but otherwise the lake itself is not utilized toward irrigation within the county. In Scotts valley and around Upper lake are a number of flowing wells, having a depth of 50 to 160 feet, the average being 81 feet. There were in all 45 of these enumerated as being on farms in 1890. The average cost of these was $90, and the average discharge 59 gallons per minute. They were sunk mainly for the purpose of watering stock, but a small amount of water is used for irrigating vegetables and trees.

Clear lake has been looked upon as an excellent reservoir site, requiring but small expenditure to utilize it for the purpose of holding water for use on land along Cache creek and out on the Sacramento valley. A detailed survey of the lake was made in 1889 by the United States Geological Survey. (*a*) Estimates were made of the outflow of the lake on two days only, the first on August 2, 1889, showing a discharge of 86 second-feet, and the second on October 4, 1889, when there was a discharge of about 4 second-feet.

As an example of the ditches of the county, may be given the Rocca and Voluntine. This takes water from Putah creek below the junction of St. Helena and Dry creeks, the head being about 7 miles from Middletown. The total length is 2 miles, the width 4 feet, and the cost was $3,000. Water is diverted through a tunnel 1,600 feet in length. The work was begun in 1883, finished the next year, and in 1889 150 acres were irrigated, this area being mainly in alfalfa.

Lassen county is in the northeastern part of California, adjacent to the state of Nevada, being east of the Sierra Nevada range. The county as a whole has an altitude of from about 4,000 to 5,000 feet, the mountains rising 2,000 to 3,000 feet higher. There are a number of broad plains of almost a desert character within this area. The soil of these is highly fertile, and whenever water can be applied large crops are produced. Without irrigation nothing will succeed except perhaps an occasional crop of small grains, the yield per acre being insignificant. Within the county are two large lakes, Eagle and Honey, the former at an altitude of over 5,100 feet, the latter at about 3,950, occupying the lowest point in that part of the country. Eagle lake has an area of about 45 square miles, has precipitous shores at many points, and is probably very deep. In contrast to this is Honey lake, occupying at times twice this area, the water being very shallow, the lake in fact occasionally disappearing completely by evaporation. The two lakes are about 30 miles apart, but the catchment area tributary to Honey lake extends almost to the shores of Eagle lake, Willow creek, one of the tributaries of Susan river, heading near a low divide east of the center of Eagle lake. It is thus possible by making a deep cut to cause the waters of Eagle lake to discharge easterly down Willow creek to Honey lake.

In the northwestern corner of the county is Big valley, traversed by Pitt river, from which water is taken for irrigation. East of this is Ash valley, in which some land is irrigated from Ash creek. Southeasterly from this latter area are the Madeline plains, having an altitude of about 5,200 feet and almost entirely destitute of water. The most important area of agricultural land is in the vicinity of Susan river and around Honey lake, the facilities for irrigation being exceptionally good. The county as a whole is devoted to stock raising, and thus the forage plants form the principal crop. Some fruit is raised, but the difficulty and expense of shipment tend to restrain development in this direction. As a rule, the methods of irrigation are crude, being those adapted for flooding

---

[a] The results of this survey are shown in Part 3 of the Thirteenth Annual Report of the Geological Survey, 1892, accompanied by a contoured map.

large areas of nearly level land at the least possible expense. Dams are built in the smaller streams and the water of the spring floods is turned out and conducted by ditches or guided by small dikes or levees, submerging as large an area as possible. The duty of water is thus relatively low, and with more careful use larger areas could be covered. The expense, however, is small, in one instance 900 acres being brought under irrigation at a cost of $1,200.

The water supply of the county taken as a whole is large, there being many small streams, and one or two rivers of notable size. Pitt river, one of the upper tributaries of the Sacramento, flows through the northwestern corner of the county, but with the exception of this nearly all of the streams flow into sinks or lakes, from which the water escapes only by evaporation. Next in size to Pitt river is probably Susan river, which flows easterly along the front of the Sierra Nevadas into Honey lake. On the opposite side of this body of water is Long Valley creek, which, also draining the face of the Sierra Nevadas, flows northerly and westerly. Both of these streams, with adjacent creeks, are of great importance in the development of irrigation in the county. No long series of measurements have been made of the available supply, but it is probably ample for all systems now projected. Artesian wells of a depth of from 200 to 400 feet have been sunk on the east side of Honey lake in the vicinity of Amadee, but at Janesville, on the western side of the lake, it is stated that borings have been unsuccessful. East of Pittville, below Big valley, are also a number of flowing wells, these having a depth of about 200 feet.

Besides the numerous smaller irrigating systems are two large projects for irrigating lands in the vicinity of Honey lake. On the west and north of this lake are the works of the Eagle Lake Land and Irrigation Company, and on the south and east of the lake those of the Honey Lake Land and Water Company. The first named company has canals taking water from the north side of Willow creek and one from the south side of Susan river, these canals heading above the junction of the streams and covering opposite sides of the valley in the vicinity of the town of Lassen. Near this place the two systems are connected by an iron pipe 22 inches in diameter crossing the valley, the intention being to transfer water from one canal to the other according to any necessity which may arise. Along each canal are storage reservoirs, in which it is proposed to hold a part of the flood waters of each stream. The supply is to be further increased by cutting an outlet from Eagle lake through the divide separating it from the head waters of Willow creek, which rises in springs within 1 or 2 miles of the shores of this lake. When this is done, Eagle lake can be used to a certain extent as a reservoir, furnishing an enormous volume of water to Willow creek, part of which can, if necessary, be carried by the iron pipe across to the canal on the south side of Susan river.

The irrigation system of the Honey Lake Valley Land and Water Company depends for water upon storage on Long Valley creek. It is proposed to construct a large earthen dam at the point where this creek enters Honey Lake valley and conduct the water thus held by a system of canals leading to the north, and covering land in the vicinity of Liegan, and northerly toward Amadee. The drainage area of the creek above the dam site is stated by the company's engineer to be 400 square miles, and it is estimated that there will be ample water to fill the proposed reservoir, which has an available capacity of 10,000,000,000 gallons. (*a*)

LOS ANGELES COUNTY is immediately south of Kern, extending from the nearly desert lands of the interior basin southerly over the Sierra Madre mountains to the Pacific ocean. The population is concentrated between the mountains and the seacoast, and agriculture is mainly confined to the same area, namely, to the coastal plains and the valleys whose drainage escapes seaward. The Sierra Madre mountains trend in a nearly east and west direction, extending from Ventura county across Los Angeles and into San Bernardino county, where apparently they culminate in Grayback mountain northeasterly from the city of San Bernardino. This mountain range is notable for its precipitous slopes and the rapidity with which the elevation increases from the base toward the summits. In fact, there are few if any other mountain ranges in the United States which as a whole rise as abruptly. This remarkable topography has, as might be supposed, a great effect upon the climate, and especially upon the humidity and precipitation. The valleys at the southern foot, even though not receiving a large rainfall, are comparatively well watered, while the lands to the northward of the range have an aridity approaching that of a complete desert.

The physical characteristics, water supply, and condition of irrigation development in Los Angeles, Orange, San Bernardino, and San Diego counties were most fully discussed by the state engineer of California, in his report upon irrigation in southern California. (*b*) This work treats in an exhaustive manner not only of the topography

---

a The discharge of Long Valley creek, as measured for the company at the dam site, was as follows:

	SECOND-FEET.
December, 1890	32
January, 1891	60
February, 1891	206
March, 1891	300
April, 1891	220
May, 1891	116
June, 1891	16

Later in the year the creek becomes almost if not quite dry. (Report of L. H. Taylor, engineer in chief.)

b Irrigation in California, Southern. The field, water supply, and works, organization and operation in San Diego, San Bernardino, and Los Angeles counties. The second part of the report of the state engineer of California on irrigation and the irrigation question. William Ham. Hall, C. E., state engineer. Sacramento, 1888.

VIEW OF CEMENT DISTRIBUTING DITCH, NORTH POMONA, LOS ANGELES COUNTY, CALIFORNIA, ILLUSTRATING METHOD OF DISTRIBUTING WATER TO ORCHARDS.

of the country, but also of the history and growth of the almost innumerable systems of irrigation now in use. At the time the book was prepared Orange county was a part of Los Angeles, and therefore in the descriptions the area now within the former county appears under the head of the latter.

The counties of Los Angeles, Orange, San Bernardino, and San Diego are collectively spoken of as forming southern California, a country quite distinct from the rest of the state in its topography and in resulting conditions. Ventura might be included, but perhaps it falls best into the coast division. The total area of these four counties is in round numbers 40,000 square miles, nearly equal that of the state of Ohio, Virginia, or Kentucky. The greater part of this area is so arid in character that the population is exceedingly scanty. It would be possible to segregate the portion of these counties extending from the ocean to the tops of the mountains, including all of the principal catchment areas, so that the piece thus cut off would contain nearly if not quite all of the population and the best of the farming lands. This tract would contain an area of, in round numbers, 6,000 square miles, three-quarters of the area of Massachusetts or about five-sixths of that of New Jersey. This relatively small area contains all of the cities and towns, the health resorts, the orchards, and the vineyards for which southern California is famed. The population in 1890 was in round numbers 173,000, a little more than that of Delaware. The remaining 34,000 square miles in Los Angeles, San Bernardino, and San Diego counties beyond the mountains contains doubtless many spots of great value, but these in the aggregate sink into insignificance compared with the 6,000 square miles nearer the coast.

The agricultural lands of Los Angeles county are mainly in San Gabriel and San Fernando valleys and upon the coastal plain. The San Gabriel valley is on the eastern side of the county, extending from near the city of Los Angeles easterly to within a few miles of the San Bernardino county line, lying thus along the foot of the Sierra Madre range. It is separated from the coast plains by the Puente hills, whose trend is in general parallel to that of the coast. From the high mountains at the north comes the San Gabriel river, the channel of which crosses the valley in a general southeasterly course. Smaller streams, coming also from narrow canyons, enter the upper or northern edge of this basin shaped valley. The San Fernando valley is a little north of west of the San Gabriel and is more nearly inclosed by high mountains than is the latter. On the south are the Cahuenga mountains and on the north the San Fernando range, this being a portion of the main divide of the Sierra Madre. The water of the streams which flow into this valley from all sides if not evaporated finally escapes at the southeastern corner of the basin, passing through the city of Los Angeles.

North of the Sierra Madres are several important valleys, some of them of great size, the water supply in general being deficient. The most notable of these valleys is that known as Antelope, lying partly in Kern county. Some of the land, as for example, around Elizabeth lake, is moist, and fair crops of forage are obtained. Several irrigation districts have been formed in this part of the county and development of the resources is progressing rapidly. Water must be obtained mainly by storage, although in the vicinity of Lancaster there are a number of flowing wells. The Antelope Valley Water Company has made surveys for the storage of waters of Piru creek, a tributary of Santa Clara river. Also, Crain lake, situated at the western apex or head of Antelope valley, has been examined for storage purposes, and it has been estimated that 75,000 acres in the upper end of the valley can be irrigated by this project.

Owing to the peculiar topography of the county, the abruptness and great altitude of the mountain range previously mentioned, the water supply of the southern part of the county is large. At the foot of the mountains the rainfall in some localities is sufficiently great for all fruits and field crops, and at other places, especially on the low grounds, there is sufficient moisture beneath the surface for the needs of plant life. However, much of the best land of the county, especially that most favorable for the production of the citrus fruits, requires irrigation, the orchards doing best in a warm, dry soil, occasionally watered. Thus, although the greater part of the agriculture of the county as far as gross acreage is concerned is carried on without irrigation, yet by far the most valuable part, the horticultural, depends immediately upon the water supply.

In this and the adjoining county of San Bernardino nearly all of the streams flow from the mountains through deep canyons, entering the valleys upon great piles or benches of loose sands and gravels hundreds of feet in thickness. Into these the water tends to sink, reappearing perhaps in springs, or cienegas, as the water-bearing lands are locally known, or in artesian wells. The irrigation works therefore are constructed in such a manner as to take water at the mouth of the canyons, or depend for their supply upon the springs or wells developed in various parts of the basin like valleys. There are thus less apparent system and regularity about the arrangement of these works than is the case in most localities where the irrigating ditches and canals head in succession down some one stream. One system of water distribution may obtain part of its water from a surface stream, another part from artesian wells, while a third source of supply may be by the development of springs in moist lands in some other part of the valley. There has been a gradual growth and evolution of the various water companies not along definite lines, and as a result the rights and property are highly complicated. Open ditches have in many localities been replaced by pipes placed under ground, resulting in great saving of the water.

The San Gabriel and Los Angeles rivers are the largest streams of the county, but even during the greater part of the year they do not reach the ocean, their waters sinking and rising in the pervious beds. Besides these are many streams having a smaller drainage area, but carrying sufficient water to be of great importance in the irrigation of the county. Among these may be mentioned San Antonio creek, whose waters are divided between lands in this and San Bernardino county. To the west are the creeks coming from San Dimas, Dalton, and other canyons, and beyond San Gabriel river, Fish creek, Sawpit canyon, Santa Anita, Eaton, Arroyo Seco, Big Tejunga, Little Tejunga, Pacoima, San Fernando, Mormon canyon, and others, some rising in the valley, as does San Jose creek. The lowest summer discharge from San Dimas canyon is about 15 miner's inches, or a third of a second-foot, and from Big Dalton about half as much. San Antonio creek has been measured at a number of times, the results as given by Mr. Hall being as follows:

APPROXIMATE DISCHARGE OF SAN ANTONIO CREEK, CALIFORNIA.

DATES.	Miner's inches.	Second-feet.
July 6, 1885	410	8.2
August 3, 1885	200	4.0
September 8, 1885	190	3.8
July 6, 1886	661	13.2
August 2, 1886	589	11.8
September 6, 1886	444	8.9

Besides these there are few if any definite measurements of the quantity of water available in the different streams throughout the year, and even if there were this would not tell the whole story as to the water supply at hand, as many of the valuable sources do not appear as running creeks. There are a few farmers and horticulturists who claim that by thorough cultivation good results can be obtained without irrigation and that the fruits raised in this way are of superior quality. The matter rests of course largely upon the character of the soil as well as upon the amount of care given by the owner. The products of fruit culture by irrigation are, as is well known, enormous, reaching in value several hundred dollars per acre. The early crops, especially upon the damp lands, do not require the application of water, and in fact there are in the county large areas which could be benefited by draining. The fairly moist lands are worth from $50 to $75 per acre and upward, depending upon their proximity to towns. With water the higher bench lands are worth from $200 to $500 per acre and even more in the so-called colonies. The water itself has been valued at $1,000 per miner's inch, or $50,000 per second-foot. The value of course depends upon the duty, and it is doubtful whether many of the water rights would sell at these figures, although there have been transfers at as high as $1,500 per miner's inch or even more. For the use of water for short times, the prices, as given later on, vary in the different localities, the charge for 100 miner's inches during the day or night being from $1 to $5. With certain companies delivering water under pressure in pipes the charge is so much per hour for the use of a hydrant, the pressure not being given. For example, 15 cents per hour is paid for water from a 2-inch hydrant and 35 cents per hour for a 4-inch hydrant.

The water storage does not play as important a part here as in the case of San Bernardino county, with its Bear valley reservoir, or San Diego county, with the Sweetwater dam. Probably the largest storage works in the county are those in the northwestern part of San Fernando valley, the reservoir being in what is known as Mormon canyon. The dam in this canyon consists of an earth embankment 75 feet high, 270 feet long on top, 136 feet thick at base, and 6 feet thick at top. This dam is stated to have cost about $10,000, and the capacity of the reservoir thus formed is given by the state engineer as follows: (*a*)

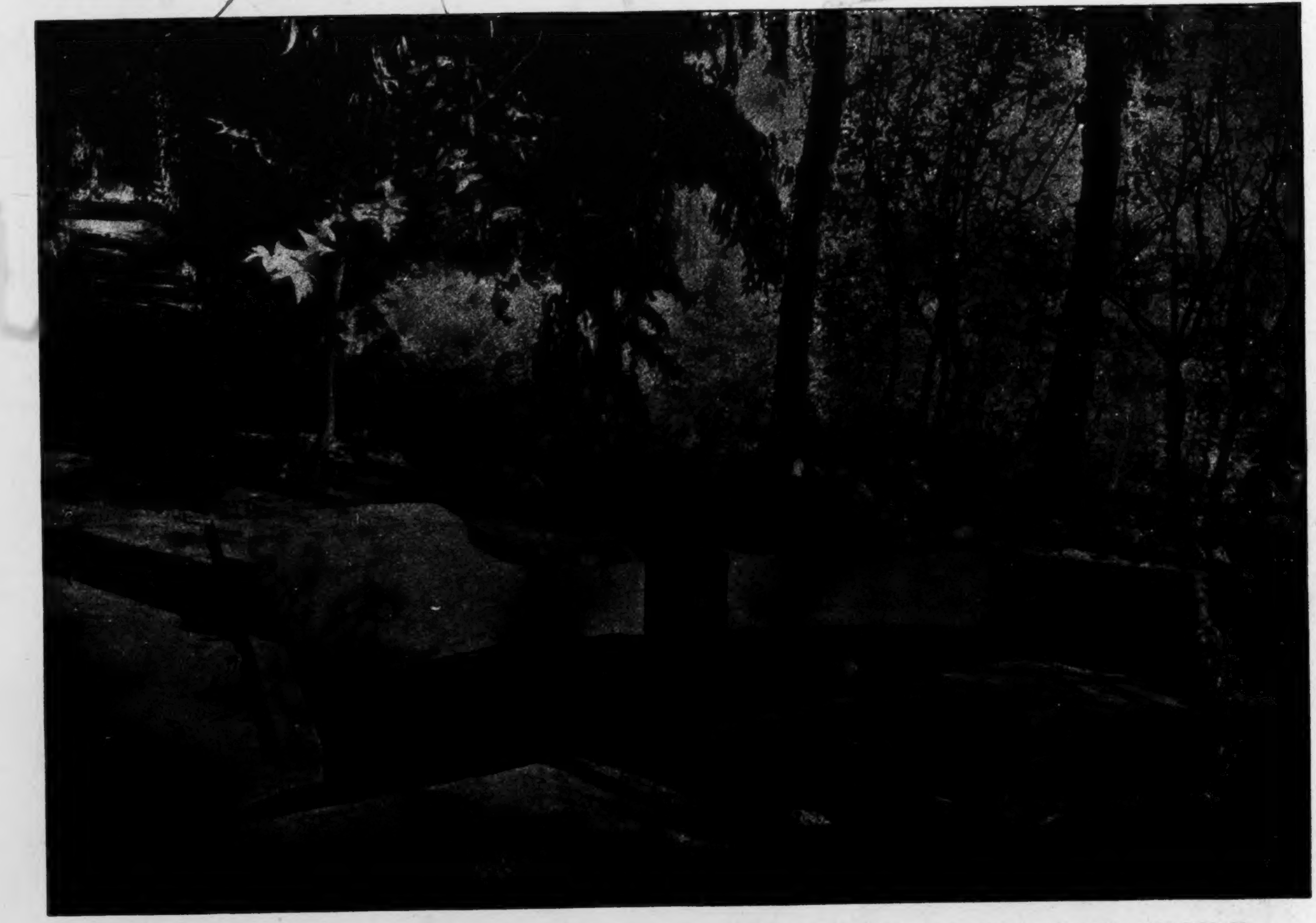
ELEVATION OF WATER PLANE IN FEET.		CAPACITIES OF RESERVOIR ABOVE GROUND'S SURFACE.	
Above sea level.	Above base of dam.	Cubic feet.	Million gallons.
1,050	10	57,834	0.43
1,060	20	563,963	4.22
1,070	30	1,887,981	14.12
1,080	40	4,005,200	29.96
1,090	50	7,084,077	52.99

There are also in the county many large cement tanks or small reservoirs built by the owners of ranches or small farms at the highest points of these. They are filled sometimes by a small continuous supply from a spring or pipe line, or are used to receive the full flow of a ditch during certain stated times.

The artesian areas in Los Angeles and Orange counties are among the most important of California. In the valleys there are within certain areas so many wells that it may be said that every fruit grower has at least one.

---

[a] Irrigation in Southern California, page 532.



VIEW OF DISTRIBUTING DITCH, LOS ANGELES COUNTY, CALIFORNIA, ILLUSTRATING METHOD OF CONSERVING WATER BY CEMENT LINED DITCHES.

In Los Angeles county 627 have been enumerated as being upon farms, the depth of these ranging from 20 to 600 feet, the average being 187 feet. Comparatively a small proportion of the water is used immediately for irrigation, since many of the wells are upon lands already sufficiently moist for the ordinary crops. The flowing wells, however, have a great value in furnishing a supply for the numerous pipe lines laid for general municipal and agricultural use, as, for example, in the case of the Chino pipe line, taking water from the vicinity of Pomona for the Chino ranch. In the Physical Data and Statistics of California is a list of 40 wells, mainly in the vicinity of Pomona. The flowing wells recorded by the census enumerators were mainly in the vicinity of Artesia, 16 miles south of the city of Los Angeles; of Compton, 11 miles south, and of Florence, 6 miles south of the same place. Many of the farmers state that they have feared to use the water for general irrigation, since, as they believe, certain areas have been spoiled in this manner by the development of alkali upon the surface. The water in general is clear and pure, in some instances containing a notable amount of sulphur. The force of the water from some of these wells is sufficiently great to drive small machinery.

Certain of the wells are reported as being sunk as early as 1870, and a large proportion were put down previous to 1880. Within the last decade the increase in number has been so rapid that the effect is being shown in diminished pressure and flow from some of the older wells. In several instances farmers report that large wells sunk near the coast have plainly affected their water supply, while others state that wells nearer the mountains have had a similar effect. Evidence on all sides points to the fact that the discharge from the wells will soon equal the capacity of the supplying area, since many of the wells on the higher ground already fluctuate with the season, diminishing in summer to such an extent that windmills are occasionally used.

At San Gabriel, 9 miles east of Los Angeles, a well was put down to the depth of 564 feet, but without reaching artesian water. Near this town on the low ground, are a number of flowing wells, furnishing water for domestic purposes, but relatively of little use for irrigation. Northwesterly from Los Angeles, in San Fernando valley, are a number of flowing wells, also at Newhall, a town on the Santa Clara river about 30 miles northwesterly from Los Angeles, and at Lancaster, in Antelope valley.

To attempt to describe the different systems of water distribution or even to satisfactorily enumerate them is not possible within the limitations of this discussion, and therefore, as in the case of other counties, brief mention is made of some of the typical or important features. Among these may be mentioned the water supply furnished by the city of Los Angeles to the adjacent farming lands, among the most valuable in the county. The water for the city is diverted by several lines, one from the Los Angeles river about 5 miles above the city, and again about a mile within the city limits, this latter conduit being known as the Zanja Madre (Mother ditch). A third supply, for the east side, is taken out about 2 miles below the head of the Zanja Madre. The upper ditch carries about 26 second-feet, or 1,300 miner's inches, this considered as being 4 "heads". This quantity of water is estimated by the state engineer to be about the average low water or summer discharge of the river.

The water is distributed by something over 50 miles of conduits within the city, fully half of these being open, and by 40 miles or more of distributaries outside the city, besides numerous farm ditches. In 1888 nearly 3,000 acres were irrigated inside the city and 8,000 acres outside, besides 3,000 acres wet by sewerage. The water is controlled by the city council, which makes the necessary regulations and appoints the superintendent or zanjero. There is more water available than is needed on the lands within the city limits, and for this reason the excess is sold to the farmers outside, these having formed associations for the purpose of distributing the water among themselves. The price for the city water is governed by the city council, the cost to persons inside the city limits being considerably less than to those outside. In each case permits are issued to the irrigators to use a zanja for the purpose of carrying 1 "head" of water for a certain definite time. The quantity is not otherwise specified and depends upon different conditions.

The charge for the use of water during the day is greater than at night, being $5 or more to persons outside the city. The quantity of water contained in an irrigation "head" is supposed to be 100 miner's inches, or 2 second-feet, but, as shown by the state engineer, it has been nearer 200 miner's inches, or 4 second-feet. Considerably over one-half of the land irrigated is in vegetables and about one-third in orchards and vineyards. Many of the best vegetable gardens are those rented by Chinamen, who pay from $15 to $25 per acre. Much of this land has without irrigation sufficient moisture for the needs of one crop and for trees, but by irrigation and thorough tilling of the soil the Chinamen succeed in producing three or four crops each year. As a rule, they flood the ground before planting, and as soon as the soil is dry they plow, harrow, and plant at once. Later, when the crop is about half grown and has been carefully weeded, a deep furrow is plowed in every alternate row and filled with water. When this ground is sufficiently dry the furrow is cultivated, and later the other rows are filled with water and cultivated in turn. This is usually sufficient for maturing the crop. When this has been gathered the ground is flooded and again planted.

Next to the Los Angeles river and the systems of irrigation depending upon it is the San Gabriel river and its works for distributing water, only a few of which, and perhaps the less important, can be mentioned. The Azusa irrigating ditch takes water from the San Gabriel river, about 2 miles from the town of Azusa, bringing it out on the east side, the Duarte ditch taking water out on the opposite or west side of the river. After leaving the river the main ditch is divided into a number of branches, covering a portion of township 1 south, range 10 west. On the line of the ditch are a few tunnels and flumes, but for the greater part of the way the water flows in open earth cuttings. The water is divided into what are known as "heads" or "runs", consisting of about 50 miner's inches, or 1 second-foot. Those entitled to the use of the water pay at the rate of $2 per day for a "head" of water. The greater part of the land irrigated is set out with orange, lemon, and deciduous fruit trees. Relatively small areas of vegetables and alfalfa are also irrigated.

The Duarte Mutual Irrigation and Canal Company has constructed a pipe line, taking water from San Gabriel river and Fish creek, the head works being about 4 miles from Azusa. Water is taken from the main stream first through a tunnel, then in a rock lined and cemented ditch for about one-half mile, later through a 26-inch pipe, a brick culvert, and cement pipes, ranging in size from 14 inches to 22 inches in diameter. Twenty shares of stock in this company call for 24 hours' run of a full "head" of about 100 miner's inches. Each irrigator is entitled to a full "run" about every 20 days, or a half "run" at intervals of about 10 days. A share is valued at $100, and is intended to furnish sufficient water for 1 acre of citrus fruits. The annual assessments vary from $3 to $4 per share. This corporation, taking water from the mouth of San Gabriel canyon, receives one-third of the whole amount, the other two-thirds going to Azusa. The accompanying figures show portions of cement ditches upon E. J. Baldwin's place at Santa Anita, and exhibit the methods of distributing and controlling the waters obtained from the streams or artesian wells.

The works of the Vineland irrigation district take water from near the mouth of the San Gabriel canyon, about 1.5 miles north of the town of Azusa, being on the east side of the river. The main ditch is 4 miles long and 3.5 feet wide. The total cost, exclusive of water right and of tunnel, was, in 1890, $27,000. The water is taken from the river into a covered flume 1,500 feet in length. The whole amount of the water is divided into "runs", each of these being not less than 80 nor more than 100 miner's inches, flowing continuously for 12 hours. The farmers are served in rotation, beginning with the lowest on the last lateral. Generally three persons are served each with a "run" at the same time. The district has constructed a tunnel 2,000 feet in length and about 5 feet in height to take out the water percolating through the bed of the San Gabriel river. In the dryest time of the year this tunnel is stated to yield 60 miner's inches.

The East Whittier conduit derives water from artesian wells and the seepage from gravels along the San Gabriel river, the wet lands controlled by the East Whittier Land and Water Company being between El Monte and Puente. A cut has been made on the west side of the river over 3,000 feet in length and having a depth of from 6 to 15 feet. Sheet piling has been driven along a portion of this cut to protect it from the river, and a flume 4 feet by 6 feet has been placed in the excavation, bringing the water out to the cement conduit. The water is conducted across the river to the east side and follows along the hillside to the East Whittier rancho. The total length of the flumes and cement conduits is about 10 miles, and the total cost approximately $60,000.

The Glendora Water Works derive a supply from Big Dalton canyon by means of a tunnel 1,500 feet in length. From this a 12-inch pipe leads the water to points where it is distributed to 3 reservoirs, from which in turn iron pipes bring the water to the town of Glendora. The total cost up to 1890 was $55,000. Only a small acreage of citrus fruits is irrigated.

The Palmdale Irrigation Company takes water from Little Rock creek, their ditch, 7 miles in length, carrying it out on the west side of the creek in a northerly direction. The total cost of this ditch is stated to have been $16,000. Stockholders in the company pay 10 cents per hour for 100 miner's inches as measured through an opening 10 inches square under a 4-inch pressure. The principal crops irrigated are alfalfa, corn, potatoes, and vegetables, together with fruit trees and vineyards.

A number of districts have been formed in this county, these being Big Rock creek, Glendora, Pomona Orange Belt, Santa Gertrudes, and Vineland. The location of these is shown on the general map for the state, and the principal facts concerning the area and valuation are given in the table accompanying this figure. The Big Rock creek district, which is located on the north side of the San Gabriel range, is reported to have been unsuccessful in its attempts to raise money, and apparently little has been accomplished. It is proposed to obtain the water supply for this district from small streams flowing northerly into the desert, but it is doubtful if a sufficient amount can be obtained to bring all of the lands under irrigation.

The Glendora district embraces 3,000 acres in the vicinity of the town of Glendora, near the eastern boundary of the county. Bonds to the amount of $170,000 have been voted, but not sold. Pomona Orange Belt district, embracing 4,000 acres in the vicinity of Pomona and east of the Glendora district, has no immediately available source of water supply, but various projects have been discussed, especially the plan of purchasing water from the Arrowhead Reservoir Company, the sites for whose storage works are in the higher valleys of the San Bernardino range. The Santa Gertrudes district comprises 2,600 acres in the vicinity of Santa Fe springs. Water will probably be obtained from what is known as New San Gabriel river. The Vineland district, in the vicinity of the town of that name, has been bonded for $50,000 or over for the purpose of developing water primarily by means of a tunnel under the channel of San Gabriel river.

MARIN COUNTY occupies the peninsula immediately north of San Francisco, and as a consequence of its position on the coast the climate is sufficiently moist, so that irrigation is not required. The principal industry is dairy farming, the city furnishing a constant market for all products of this kind. Fruit raising, especially on the inland side of the county, is becoming of importance as the suburban population increases. On the side toward the ocean the fogs and winds render the lands less favorable for fruit culture, but the moisture in the air adds to the value for grazing purposes.

MARIPOSA COUNTY is north of Fresno, extending from the summits of the Sierras westerly to the San Joaquin plain. It thus comprises a great range of topographic features from the foothills to the high mountain peaks. Within this county is the celebrated Yosemite valley, through which flows Merced river, a stream of considerable importance for irrigation in the San Joaquin valley. In the county, irrigation is little practiced, for the agricultural land in the narrow valleys usually receives sufficient rainfall for cereals and forage crops. The fruit trees are sometimes watered, especially those on the lower lands to the west. For this purpose the old abandoned mining ditches have been utilized and other works have been built.

In the higher portions of the county there are numerous springs, and the water supply is well distributed, so that irrigation can be carried on at many points. The smaller streams when they reach the lower grounds usually dwindle, and in the latter part of June or first of July become dry, so that in order to utilize these completely for the irrigation of fruit trees it will be necessary to construct storage reservoirs. The irrigating ditches now in use are mainly of from 1 to 2 miles in length and are owned by the individual farmers whose lands are partly watered. In a few instances pumps are used to raise water to orchards on the hillsides. Probably the irrigating system of most interest is that in the vicinity of Coulterville, the ditches deriving water from Maxwell creek, a short distance above Merced river, and also from this latter stream. One of these ditches, 2 miles in length, supplies water to a Leffel turbine, which in turn drives a pump, elevating water at the rate of from 6,000 to 10,000 gallons per hour through about 800 feet of pipe a vertical distance of 120 feet to a large reservoir, and from this and a second reservoir it is distributed to the orchard.

MENDOCINO COUNTY lies south of Humboldt and west of Lake county, and its surface, like that of surrounding areas, is mountainous, the valley area being relatively small. Lumbering is the principal industry, the county being within the celebrated redwood belt of California. General agriculture, stock raising, and fruit growing, though relatively of less importance, are gradually developing and demanding larger areas. Irrigation is practiced to a very small extent and that merely for gardens, fruit trees, and patches of alfalfa, mainly in the vicinity of Ukiah, Pomo, and other towns. The rainfall as a whole is large, averaging over 30 inches per year, but occasionally is less than 20 inches in depth, and were it not for the long, dry summer the artificial application of water would not be thought of. Even with these conditions two crops of alfalfa can usually be obtained, but with watering five crops are cut. The smaller streams are usually perennial, but the larger creeks, especially those of the upper Russian river, sometimes become nearly or quite dry at points in the valleys. As a whole, however, it may be said that the water supply of the county is large, and little difficulty will be encountered in this regard toward increasing the area under irrigation.

MERCED COUNTY lies across the San Joaquin valley north of Fresno, and thus includes the fertile agricultural lands from the foothills of the Sierra Nevadas across to those of the coast ranges. Most of these lands have been owned in large bodies and utilized to a great extent for the cultivation of wheat and other cereals. These are fairly successful without irrigation, but a full crop can not be depended upon every year. Irrigation was introduced on a large scale in this county, but it was found by the land owners that their gains could be greatly increased by subdividing the larger holdings into small fruit farms and founding colonies, of which there are several, Rotterdam, British, Deane, Yosemite, and others. It is stated by some of the largest land owners in California that irrigation on a large scale for wheat and other cereals has not paid in the long run.

On the nearly level grounds of this county large areas of field crops have been irrigated by means of systems of checks or levees of from 1 to 2 feet or more in height, and so built that the lower one backs up the water to the foot of the next higher. When a field has been prepared in this manner, one or two men can irrigate from 40 to 50 acres a day, or with an ample supply of water even up to 100 acres. On some of the lands two crops per year have been raised. For example, after harvesting an early crop, as of barley, the fields are planted in what is known as Egyptian corn, which, however, must be irrigated. In many places in the county water stands within about 10 feet of the surface, and after trees and vines are two years old they seldom need irrigation. The annual charges for water must usually be met, since these are an annual lien upon the land.

Hay, wheat, barley, and other grain, as stated above, are often raised successfully by dependence upon spring rains. As showing the fluctuations, the following statement of success or failure in "dry" farming is instructive: in 1869 a paying crop was raised; in 1870 and 1871 the crops were a failure; in 1872 paying; in 1873, 1874, and 1875 partial crops only were raised; in 1876 paying; in 1877 failure; in 1878 paying; in 1879 failure; in 1880 paying; in 1881, 1882, and 1883 partial; in 1884 paying; in 1885 partial; in 1886 paying; in 1887 failure; in 1888, 1889, and 1890 paying. This record, while perhaps not applying to all farmers, serves to give the degree of confidence to be placed in nonirrigated crops.

The principal streams of the county are the Merced river, Bear and Mariposa creeks, and others coming from the mountains on the east, and the San Joaquin river, which flows northwesterly through the lowest grounds. The mountain streams rise far to the east among the summits of the Sierra Nevadas, their catchment basins being largely in Mariposa county. The discharges of Bear, Mariposa, and Chowchilla creeks, as estimated by the state engineering department (*a*), are shown in the following tables. Their watersheds do not extend back to the regions of perennial snow, and therefore their flow is characterized by sudden rises after heavy rains.

ESTIMATED DISCHARGE IN SECOND-FEET OF BEAR CREEK AT BASE OF FOOTHILLS, CALIFORNIA.

(Drainage area, 166 square miles.)

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1879	0	25	57	54	0	0	0	0	0	0	0	18	13
1880	25	61	31	321	23	0	0	0	0	0	0	115	48
1881	169	214	48	6	0	0	0	0	0	0	0	0	36
1882	0	33	100	130	0	0	0	0	0	17	25	17	27
1883	66	33	170	100	50	0	0	0	0	0	0	0	35
1884	17	660	913	660	330	170	66	0	0	0	....	....	....

ESTIMATED DISCHARGE IN SECOND-FEET OF MARIPOSA CREEK AT BASE OF FOOTHILLS, CALIFORNIA.

(Drainage area, 122 square miles.)

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1879	0	20	45	43	4	0	0	0	0	0	0	15	11
1880	20	49	24	24	18	12	0	0	0	0	0	92	20
1881	134	171	38	5	0	0	0	0	0	0	0	0	29
1882	0	24	74	98	0	0	0	0	0	0	18	12	19
1883	49	24	122	73	37	0	0	0	0	0	0	0	25
1884	12	488	671	488	244	122	49	0	0	0	....	....	....

ESTIMATED DISCHARGE IN SECOND-FEET OF CHOWCHILLA CREEK AT BASE OF FOOTHILLS, CALIFORNIA.

(Drainage area, 268 square miles.)

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1879	8	56	63	48	14	0	0	0	0	0	0	12	17
1880	5	107	19	1,206	53	27	0	0	0	0	0	201	145
1881	295	375	83	11	6	0	0	0	0	0	0	27	66
1882	54	164	1,168	268	54	0	0	0	0	0	53	27	149
1883	80	53	268	134	107	0	0	0	0	0	0	0	54
1884	27	1,340	1,608	1,072	804	804	268	27	0	0	....	....	....

The principal gaugings on Merced river were made at Merced Falls, above all diversions by irrigation canals, and from these and other measurements the mean monthly discharge has been computed, as shown in the following table:

DISCHARGE IN SECOND-FEET OF MERCED RIVER AT MERCED FALLS, CALIFORNIA.

(Drainage area, 1,076 square miles.)

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1879	354	1,506	2,098	3,120	3,336	3,336	968	172	75	75	172	646	1,323
1880	387	753	867	4,250	4,842	5,111	2,744	753	323	269	237	1,291	1,814
1881	2,044	3,443	1,560	2,798	4,412	3,336	1,566	377	129	75	75	323	1,673
1882	173	753	1,506	2,260	3,658	3,336	1,076	215	129	484	387	237	1,184
1883	344	355	915	2,260	5,488	4,412	1,184	377	237	183	161	173	1,341
1884	237	2,712	3,820	4,896	5,434	6,510	4,356	1,130	237	172	....	....	....

a Physical Data and Statistics of California. Tables and memoranda of data. Collected and compiled by the state engineering department of California. William Ham. Hall, state engineer. Sacramento, 1886. Pages 408, 434-442.

Artesian wells are found west of the main line of the Southern Pacific railroad, beginning at distances of from 2 to 5 miles from it, the artesian area extending to the low grounds along the San Joaquin river. The general location of many of the older of these wells is indicated by the circles upon the accompanying map. The total number enumerated upon farms in the census year was 112. These were from 170 to 700 feet in depth, averaging 326 feet, and having an average discharge of 65 gallons per minute. Very few were used for irrigation. Most of them furnished a pure, clear water, employed for domestic purposes, but mainly for cattle. The water from a number of the wells contained a notable percentage of earthy salts, and was reputed to possess medicinal qualities.

The principal irrigation works of this county are those owned by the Crocker-Huffman Land and Water Company, taking water from Merced river to irrigate lands on the east side of San Joaquin valley, and those of the San Joaquin and Kings River Canal and Irrigation Company, taking water from the San Joaquin river in Fresno county to cover land on the west side of that stream. Besides these are the East Side canal, west of Merced, and a number of smaller canals and ditches owned by individuals and associations. Among these may be mentioned the Merced Falls, Murray Mill, Snelling, Scott, and Ruddle ditches, these being on the north side of Merced river, and the Feldhaus and Reed, Hamlin, and the Griffith and Shaver ditches, on the south side of Merced river

The Merced canal, owned by the Crocker-Huffman Land and Water Company, takes water from the south side of Merced river, about 3 miles below Merced Falls. It is 27 miles long, from 60 to 70 feet wide on bottom and 100 feet wide on top, the estimated capacity at the head being 4,000 second-feet. At two points along the line it passes through tunnels, one of which, with approaches, is 5,000 feet long, the other 1,650 feet in length. These are 22 feet wide and 12 feet high. The canal empties into a large reservoir known as Lake Yosemite, situated about 5 miles northerly from Merced. The dam forming this reservoir is 4,000 feet long, 275 feet thick at base, and 20 feet thick at top, the greatest height being 60 feet. The estimated contents of the reservoir are 20,000 acre-feet. Water by means of pipe is conducted to Merced city, the head or pressure being about 90 feet. From the main canal are a number of laterals, carrying the water for irrigation to the various colonies and farming lands. The total cost of this irrigation system is upward of $2,000,000. It has been constructed to irrigate lands owned by Messrs. Crocker, Huffman, and others, these great tracts being subdivided into lots of 20 acres, on each of which it is expected a settler or colonist will be able to make a living by raising grapes and other fruits. Land, with water right, is sold at from $50 to $150 per acre and upward, subject to an annual charge of $1 per acre for the use of the water.

The main works of the San Joaquin and Kings River Canal and Irrigation Company obtain water from San Joaquin river and from Kings river through Fresno slough, the head of the main canal being situated in Fresno county, about 35 miles westerly from Fresno. The general course of the canal is northwesterly along the western side of the San Joaquin valley across Merced county and into Stanislaus. The total length of the main canal is 71 miles, the width being 30 feet on bottom and 60 feet on top. The total cost of the system has been over $1,500,000. The company owns and controls the main canal, the branches and distributaries belonging to other parties. Each year water rates are voted by the board of directors, those for the census year being for alfalfa lands $2.50 per acre, for cereals $2, for fruit trees and vineyards $2, and for vegetable gardens $5 per acre.

MODOC COUNTY is in the northeastern corner of the state, adjoining Oregon and Nevada. In the western end it consists largely of broad lava covered plateaus, having an altitude of about 5,000 feet. The surface is extremely rough and irregular, being broken by mountain masses. In the eastern end is a range known as Warner mountains, crossing the county in a northerly and southerly direction, and consisting of great blocks of the earth's crust tilted gently to the west, the broken edges rising abruptly from the plains on the opposite side. On each side of this range are basins resulting from the tilting of the mountain masses, these being in part occupied by lakes which have no visible outlet, their waters escaping by evaporation. The land around these lakes is usually low and marshy, and as the lakes fluctuate in height, rising at the time of melting snow and falling during the heat of summer, the area increases or diminishes by a large amount.

On the east side of Warner mountains is Surprise valley, extending along the foot of the steep declivities. This is occupied largely by the chain of lakes known, respectively, as Upper, Middle, and Lower Alkali lakes. On the opposite (western) side of the range, and at the foot of the relatively gentle inclination of the mountains, is the north Goose lake, and on the south the marshes of the south fork of Pitt river. Goose lake at some former time in its history overflowed into the north fork of Pitt river, but now this stream obtains its water wholly from creeks draining Warner mountains. Flowing southerly, the north fork joins the south fork, which comes from the opposite direction, and, uniting, the stream flows westerly for about 40 miles and then turns south through Big valley, entering Lassen county. At short intervals along its course dams have been placed, diverting the waters upon the meadows and grass lands.

Owing to the distance of this county from railroads, the principal industry has been stock raising, and agricultural operations have been directed mainly toward producing forage plants and cereals for home consumption. Little can be raised without irrigation, although an occasional crop of small grains is said to have been successful. Irrigation, as practiced, is in its crudest state, each farmer or stock raiser having taken up lands near a spring, creek, or other stream, from which water is diverted in the cheapest manner possible. Thus, although the aggregate area irrigated is large, the investment and average value of products are small. By far the greater part of the lands are irrigated for forage and pasturage, so that the products do not appear in the agricultural returns. The irrigated lands are to be found along the foot of Warner mountains, both on the east and west, each small stream being utilized when swollen in spring by the melting snows. Also, as previously stated, there are numerous localities along Pitt river and its tributaries.

The country about the south end of Goose lake was examined in August, 1889. At that time the lake surface was reported to be about 5 feet below its average or normal low water plane owing to the excessively dry seasons during the two or three years preceding. Each winter the lake ordinarily fills nearly to the level of its former outlet and during summer recedes by evaporation, losing about 3 feet of water in depth. Taking a series of years, the average elevation is probably lower than in the early part of the last decade. Proceeding southerly along the old outlet, the ground was found to be for a mile or more at an elevation of 6 feet above the water surface of August, 1889, gradually falling until, at a distance of 6 miles, the ground was found to be practically at the same level as that of the water in the lake. A long and relatively shallow cut would thus convert this body of water into a reservoir, supplying water for lands along Pitt river. The extent of arable land which can be irrigated from the north fork of Pitt river is somewhat limited. Canals could be diverted at a point about 6 miles northeasterly from Alturas, covering all the good land in that vicinity. Also other canals, taken out on both sides of the river about 5 miles west of Alturas, could be constructed to irrigate Warm Spring valley. At a point 6 miles north of Lookout canals could be carried out on both sides covering all the good lands, of which there are approximately 70 square miles.

In Surprise valley, along the eastern front of Warner mountains, from Fort Bidwell to Eagleville, are a number of flowing wells, ranging in depth from about 50 to 150 feet and over. On the western side of the range no successful artesian wells have been reported. At Alturas a well was sunk in 1890 to the depth of 400 feet, but failed to obtain flowing water. In the whole county there were reported to be 12 flowing wells upon farms in the census year, the depth ranging from 56 to 280 feet, and the average discharge being 50 gallons per minute.

MONO COUNTY lies east of the Sierra Nevadas, between Alpine on the north and Inyo on the south. It thus includes a narrow strip of country along the eastern face of the mountains, together with some of the valley region near the Nevada line. The principal industries are mining, lumbering, and cattle raising, the altitude as a rule being too great for most of the agricultural operations. The lands reported as irrigated are valley bottoms flooded for the production of hay. This area is in most respects similar to the western part of Nevada, and, like the adjoining counties, with the decline of mining operations population and wealth have rapidly diminished. In the northern end of the county are the head waters of the east and west forks of Walker river, both of these streams being of great importance in the development of irrigation in Douglas, Lyon, and Esmeralda counties, Nevada. To California, however, their waters have relatively less value, since they are used mainly for irrigating common grasses.

MONTEREY COUNTY is one of the southern coast counties, lying west of the southern part of San Joaquin valley. It includes the greater part of the Salinas valley, which is formed by the Santa Lucia mountains, stretching along the coast, and to the east by the nearly parallel Gabilan range, the summits of these latter mountains being the boundary of San Benito county. The Salinas river, rising in San Luis Obispo county, flows northwesterly between the parallel ranges through a broad valley and empties into Monterey bay, on the southern shore of which is the celebrated health and pleasure resort of Monterey. In this and the smaller valleys agriculture is carried on successfully without irrigation in spite of the fact that the annual rainfall is very small, averaging probably from 10 to 15 inches. The small amount of the annual precipitation is in part compensated by the relatively moist winds from the ocean. Most of the best agricultural land has been covered by land grants, and is still held in large bodies, used principally for grazing. Irrigation, where practiced, is conducted on a small scale, the waters of springs and rivulets being utilized by individuals having land conveniently situated. On the low grounds near the mouth of Salinas river there were reported to be 60 flowing wells upon farms in 1890, most of these being not far from Castroville. They range in depth from 60 to 189 feet, the average being 136 feet, and the discharge only about 3 gallons per minute. They are reported to fluctuate with the season, many of them ceasing to flow in summer and in winter barely discharging at the surface of the ground. At Salinas, about 10 miles from the coast, most of the deep wells are pumped by windmills. The water generally contains a perceptible amount of mineral matter and in a few cases has an oily scum. At Pleyto, in the southern end of the county, there are also reported to be flowing wells.

The canal of the San Bernardo and Salinas Valley Canal and Irrigation Company takes water from Salinas river in the southern part of the county not far from the town of Sargent. It is built on the east side of the river for a distance of 6 miles. The average width is 10 feet, and the cost was $25,000. The canal, owned by a corporation, was begun in 1884 and first used about 1888. The principal crop irrigated at present is alfalfa. The water supply is fairly good, although the river is dry at times, the water sinking in the bed of the stream.

NAPA COUNTY is one of the small counties north of San Francisco and bordering on San Pablo bay. It includes a number of broad valleys in which agriculture has been carried on for many years. The chief source of wealth is in the vineyards, whose products are known throughout the country. Besides grapes, almost every variety of the so-called deciduous fruits is produced, as well as notable quantities of olives, oranges, and lemons. Irrigation is not practiced on a scale sufficiently extensive to require enumeration. There are a few flower gardens and small areas cultivated by Italians and Chinese, to which water is applied during droughts, being lifted by wheels or pumps. As a rule the valley lands need drainage rather than irrigation.

NEVADA COUNTY extends from the extreme eastern boundary of the state over the Sierra Nevadas to the Sacramento valley. It is from 10 to 20 miles in width and about 70 miles in length. On the eastern side of the mountains are streams tributary to Truckee river, the outlet of Lake Tahoe, and one of the most important sources of water supply for the state of Nevada. Comparatively little of the water of this stream is utilized for irrigation in California, but it is employed in furnishing water power for mills and for floating logs down to the mill ponds. The fluctuations of Truckee river and its tributaries are discussed in the description of Washoe county, Nevada, since for the agricultural development of that area it is of the greatest importance.

West of the summits of the Sierra Nevadas are a number of localities in which water is held in reservoirs to supply the canals and flumes built for hydraulic mining. This industry has been of first importance, but owing to the unfavorable legislation it has almost gone out of existence. The ditches built for hydraulic work are utilized to a large extent by the mills, and water is also sold by the miner's inch to farmers and fruit growers. The prices paid have been from 10 to 12.5 cents per miner's inch for 10 hours, or from $3 to $6 per acre each season. There is considerable complaint on account of the high rates charged for water, it being asserted that under favorable circumstances the prices should not exceed $2.50 per acre per annum. The orchardists depending upon mining companies for water have little security as to the permanence of supply. Should this water be needed for mining purposes they are liable to be deprived of it, thus imperiling their trees and vines. The principal ditch systems from which water is used for irrigation are the Excelsior, Eureka Lake, Milton, North Bloomfield, and South Yuba. Besides these are many small private ditches depending upon springs or creeks. Water is used mainly for fruit trees and alfalfa, the cereals not requiring irrigation throughout the greater part of the area. On the west fruits even of a semitropic character are raised to perfection, so that this industry promises to surpass mining in value of products.

ORANGE COUNTY lies along the coast southwesterly from San Bernardino county and south of Los Angeles county, from which it was set off in 1889. It includes the lands from the coast range of hills or mountains to the Pacific ocean, extending from Coyote creek southwesterly beyond San Juan Capistrano. The coast range or Santa Ana mountains, as they are locally known, are relative to the Sierra Madre of little importance as furnishing a water supply, since the altitude rarely exceeds 5,000 feet, and the slopes are not as steep. From the base of these mountains the ground falls rapidly seaward, the greater part being less than 300 feet in elevation. Much of this low land is sufficiently moist for agriculture, and on some parts of the plain the conditions are favorable for flowing wells.

The Santa Ana river has cut a deep gap in the coast range, through which its waters escape from the San Bernardino valley seaward. This canyon extends in a nearly east and west direction, having a total length of less than 10 miles and a width from one-fourth to a mile. At the upper end of the canyon the river is at an elevation of about 420 feet and at the lower end of about 275 feet. The fall within the canyon is thus favorable for the diversion of water, rendering it possible to take out irrigating canals commanding almost any part of the coastal plain.

Fruit raising is the principal industry of the county, the returns from this being usually large. Oranges and lemons are raised to some extent, but are relatively of less importance than in San Bernardino and Los Angeles counties. Large areas were formerly devoted to vineyards, and great quantities of grapes were raised, but in 1889 and 1890 disease destroyed nearly if not quite all of the vines, resulting in the loss of millions of dollars. The returns from oranges, from groves of 6 years of age and upward, are reported to be $400 per acre and upward; from English walnuts, from trees 8 years old, $300 per acre. In many localities the orchards require comparatively little, if any, water, especially for walnuts and deciduous fruits. The orange groves, being usually on a dryer soil, are watered every 30 or 40 days during the interval from April to October.

The field crops, such as barley, corn, and other cereals, are irrigated to a small extent. Many of the lands when in a natural state are not sufficiently moist for these crops, but they can be made productive by a single watering during the winter, if the ground is thoroughly soaked. An important crop in parts of this county is the peanut, the acreage being of considerable extent. Spring crops rarely require irrigation, and these when gathered early in the season are followed by a second crop, which, however, may require water. For example, barley sown in the latter part of December is harvested early in May, and the ground is planted at once to potatoes, corn, or pumpkins. Lands in the county without water are quoted at values from $25 to $100 per acre and upward, depending upon the moisture of the soil, while those under ditch were worth from $150 up to $500 per acre or more, in some instances the annual value of the crop being apparently as much if not more than that of the land.

The water supply for the county is obtained from the Santa Ana river at points within its canyon, also from its tributary, Santiago creek, and smaller streams coming from the coast range. In addition to the surface drainage, considerable water is obtained from underground sources by the development of springs and artesian wells, the more important irrigation systems being supplied by the surface drainage. In the canyon of the Santa Ana river about halfway of its length the bed rock outcrops in places and apparently forces to the surface the water percolating through the gravel and bowlder filled channel. Thus, although the channel of the river may be dry some miles above and below this locality, yet at this point the river is perennial, the discharge sinking in summer to as low as 40 second-feet.

Santiago creek drains a portion of the coast range, having a catchment area of less than 80 square miles. It passes out of the range through a narrow gorge, thus affording a perennial supply to lands below this point, this, with the Santa Ana river, being the principal stream of the county. The creeks draining the high grounds to the south are intermittent in character, and during the summer season their waters rarely reach the sea.

In the western end of the county, in the vicinity of Garden Grove and Westminster, are a large number of flowing wells, so many in fact that it is currently stated that every farmer has one. They are little used for irrigation on account of the moist character of the soil in the vicinity, water sometimes standing within 3 or 4 feet of the surface. Their principal value is in furnishing water for domestic use and for gardens. The total number of wells reported as being upon the farms of the county was 649, the depth ranging from 26 feet to 450 feet. The average depth was 147 feet, the average cost was $209, and the average discharge was 110 gallons per minute, or 0.24 second-foot. Unfortunately the flowing water does not rise to the level of the lands most requiring irrigation, and attempts made at such points have often been unsuccessful. As in the case of Los Angeles county, many of the farmers were prejudiced against the use of artesian water for irrigation, believing that good lands had been thus ruined by the development of alkali upon the surface following the too lavish application of this water.

The three principal systems of the county are, first, that on the north side of the Santa Ana river irrigating lands in the vicinity of Anaheim; second, that on the south side of the river covering lands in the vicinity of Orange, Santa Ana, and Tustin, and, third, that receiving water from Santiago creek and irrigating the grounds above the canal system just named. The most northern system has been owned for many years by the Anaheim Union Water Company, which constructed or bought over 100 miles of open canals and branches, covering 12,000 acres, of which about 7,000 were usually irrigated. The water was sold by "heads" at varying rates, the charge during summer, when the supply was scanty, being greater than in winter. A "head" was considered to be about 100 miner's inches, and the privilege of buying or hiring one of these "heads" was limited to stockholders in the company. The summer rate was for the census year 50 cents per hour during the daytime and 25 cents per hour at night, while the winter rate was 25 cents per hour for day and 15 cents per hour for night water.

The Santa Ana Valley Irrigation Company had in the census year probably the largest and most important irrigation canal in this part of the state. Water was taken from the south side of the Santa Ana river at a point about 12 miles above Orange by a canal, a portion of which was lined and cemented. The canal, following along on the south side of the river in the canyon, passed by means of a tunnel through a spur of the hills and then divided, commanding 20,000 acres within the old rancho Santiago de Santa Ana. The maximum quantity in the canal as measured by the state engineering department was 45 second-feet. The charge for water per 100 miner's inches was 20 cents an hour during the daytime and 10 cents an hour at night. In times of scarcity the charges were 30 cents an hour during the day and 15 cents an hour at night. The sales of water were made to the holders of shares of which there were 20,000, or one for each acre under the ditch. The original cost of a share was from $5 to $10 and the value during the census year was $20.

The water from Santiago creek was taken by the Serrano and Carpenter Water Companies, who joined in constructing diverting works, dividing water after it had been taken into one canal. An interesting feature of the headworks was the submerged dam which intercepted water percolating through the channel. At the narrowest part of the pass, at the outlet of the creek, an excavation was made to bed rock, the open cutting 12 feet wide extending across the channel of the creek from wall to wall. This was filled with a puddle wall of clay. The efficiency of this wall in stopping the seepage was shown by the fact that the willows and cottonwoods growing along the channel below this point died, apparently from lack of moisture. Water is distributed by these companies mainly by pipes. The summer supply is probably about 5 or 6 second-feet, or at times even less, and the area irrigated was approximately 2,000 acres.

In this county one successful irrigation district has been formed, covering land in the vicinity of Anaheim. The total area is 32,500 acres, and the assessed valuation is stated to be $1,245,742. Bonds to the amount of $600,000 have been voted, this being at the rate of $18.46 per acre, and half of these have been sold at 90 per cent of par value. This is reputed to be one of the best irrigation districts in the state as regards its organization and financial ability. It includes large areas of land which have been under cultivation for years, some of which set out to orchards is worth from $1,000 to $2,000 per acre. The unimproved land within the district is probably worth upward of $100 per acre. It is proposed to purchase the property of the Anaheim Union Water Company and to develop other sources of supply.

PLACER COUNTY is south of Nevada county, and, like it, extends from the state line on the east down the slopes of the Sierras in a long, narrow strip to the Sacramento plains. On the eastern edge is Lake Tahoe, this body of water being partly in the state of Nevada. The drainage area tributary to this lake is small, and the greater part of the precipitation within the county flows westerly into the American, Bear, and other rivers. As in the case of Nevada county to the north, the cultivation of fruit is rapidly becoming a most important industry, especially in the foothill region between the mountains and the Sacramento valley. Localities in former years celebrated for mineral wealth are again becoming known through the excellence of the fruits cultivated in the vicinity. Irrigation is widely employed, although there are still many orchardists who claim that they can raise as good or better fruit without the artificial application of water. It is necessary, however, to cultivate the ground thoroughly and keep the surface of the soil well pulverized to prevent excessive evaporation during the long summer drought. Most of the cereals are raised without irrigation, and in many localities alfalfa is seldom watered.

The principal irrigation system is that belonging to the South Yuba Water Company. This originally derived water from Bear river, but as this stream often became nearly dry during July it was found essential to draw upon other rivers. A canal has been constructed by which water is taken from South Yuba river and from storage reservoirs in Nevada county to supply the deficiency in Bear river. The total length of the main ditches and branches in both Nevada and Placer counties is stated to be about 380 miles. There are also 8 important storage reservoirs high among the mountains and a number of smaller distributing reservoirs near the localities to be served. Water is sold at the rate of 30 cents per miner's inch a day for 5 months, or at the rate of 12.5 cents a day for 1 year. This is equivalent to $45 per miner's inch per year. This quantity of water is considered to be sufficient for from 4 to 6 acres or even up to 10 acres when used with care. Thus the cost of water may be stated to range from $4.50 up to $11.25 per acre per annum.

PLUMAS COUNTY is in the northern part of the Sierra Nevada range, being bounded on its eastern edge by the watershed of the Great Interior basin. In spite of its mountainous character it contains a number of open valleys suitable for agriculture, the principal among these being at altitudes of nearly 5,000 feet and upward. As in the adjoining counties, mining and stock raising are the principal industries, dairy products assuming considerable importance. The lack of facilities of transportation has retarded development to a large extent. The rainfall is relatively heavy and the ordinary operations of agriculture are successful without irrigation, wheat, barley, oats, and other cereals being raised by "dry" farming, but water is applied artificially for the purpose of making meadows and increasing the quantity of hay. The area reported as irrigated includes much of this land, upon which water is turned in the spring and allowed to find its way with little guidance over the fields. In this respect this and other counties of northern California may be compared to those of Nevada, in which large acreages are irrigated or partially flooded in the cheapest manner possible. From the high mountains surrounding each valley almost numberless streams issue, each of the larger of these being diverted from its natural course and by means of short ditches forced to cover the lands of one or two ranchers in the valley.

The water used for irrigation is obtained to a large extent from ditches built by the miners, but besides these are the numerous short ditches constructed by the owners of ranches taking out water generally for the use of one or two persons. The land which is not under ditch but is utilized for pasture is worth from $3 to $5 per acre, while the same with water is quoted at from $20 to $50 per acre. A number of fruit trees have been set out in various parts of the county, and many of these are thriving and producing sufficient for local consumption. In the southeastern corner of the county and extending southerly into Sierra county is a broad basin known as Sierra valley. This is drained by the head waters of Feather river, but in many respects is similar to the valleys of the Great Interior basin. Like them it is filled to a depth of 1,000 feet or more with recent sedimentary deposits in which the conditions are favorable for obtaining flowing wells. The first wells were drilled probably about 1863 or 1864, but the number was not greatly increased for nearly 20 years. When the fact was fully appreciated that flowing wells could be obtained in nearly all parts of the valley many were put down, the result being that in some instances the discharge from old wells ceased and all decreased with more or less rapidity. In 1890 there were reported as being on farms in Plumas county 159 of these flowing wells. The depth of these ranged from 60 to 1,132 feet, the average depth being 550 feet. The average cost per well was $165 and the average discharge 40 gallons per minute. The small average cost is due to the fact that in the Sierra valley at least the wells are drilled rapidly through clay, only one length of casing being used, that being placed at the top in order to keep out surface water. The clay stays in place remarkably well and does not require mechanical support. The water is generally warm, sometimes hot, and is used mainly for watering stock, a small amount being employed for gardens and for raising vegetables.

SACRAMENTO COUNTY includes a portion of the central part of Sacramento valley east of the river and extending to the foothill regions. The greater part of the area is less than 100 feet above sea level, and on the western and southwestern sides the lands in their original condition were overflowed and marshy. Extensive systems of dikes have been built, reclaiming valuable tracts whose surface, though below water level, is covered by a soil of wonderful fertility. Adjoining these are extensive areas at a slightly greater altitude, but kept moist by the presence of the ground waters saturating the subsoil or lower layers. Still further to the east are the higher grounds, also of great fertility, but subject to summer droughts. Irrigation is practiced to a relatively small extent, since all the cereals are successfully raised upon the broad plains, water being employed mainly for orchards and vineyards on the higher grounds of the county. In the southwestern prolongation of the county lying between Mokelumne and Sacramento rivers are a number of large islands reclaimed by dikes and upon which flooding can be practiced, if required. This can hardly be called irrigation in the sense in which the word is ordinarily used, and therefore these areas of swamp lands have not been included among the irrigated farms.

Water for a large proportion of the irrigated orchards is obtained from wells varying in depth from 10 to 40 feet. This is pumped by means of windmills or by steam or horse power. The wind can usually be depended upon from April to August, but in the latter part of the summer is often light and fickle. In other respects this method of obtaining water is usually preferred by owners of small orchards. The cost of the windmills is placed at from $75 to $110, of pumps at from $15 to $40, and of wells at about $1 per foot in depth or less for the more shallow. A large windmill having a wheel of about 14 feet in diameter and driving two 6-inch pumps will usually furnish sufficient water for 5 acres. Various forms of steam pumps are used, depending largely upon the height to which water must be raised. In this county there are several deep wells, but it is doubtful whether any of them can be classed as artesian. On Tyler island, 30 miles south of the city, is a well 102 feet deep, in which water rises to within 6 feet of the surface. Near Arcade, about 8 miles northeasterly from Sacramento, a well was drilled to the depth of 2,160 feet, at a cost, it is stated, of $30,000, but without success so far as flowing water is concerned. Other wells near Sacramento have been drilled nearly 600 feet deep with the same result. West of Sacramento, near Davisville and Woodland, in Yolo county, wells have been drilled to depths of 200 feet or more. The water in these rises nearly to the surface, and in the case of one at least flows during a part of the year. Further to the southwest are flowing wells north of Suisun and San Pablo bays.

Measurements of the amount of water flowing in the streams of this county have been made by the state engineer, as previously noted. The total discharge of Sacramento river at its mouth has been estimated for the period extending from 1879 to 1885, inclusive, as shown on a preceding page. Computations of the discharge of Dry creek were also made by the state engineer, giving its discharge at the base of the foothills, and of Cosumnes river, the most northern tributary of San Joaquin river. The following table gives the fluctuations of this stream, the quantities applying to a point within the foothills above Deer and Carson creeks:

DISCHARGE IN SECOND-FEET OF COSUMNES RIVER AT LIVE OAK SUSPENSION BRIDGE, CALIFORNIA.

(Drainage area, 580 square miles.)

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1879..........	290	1,218	1,740	3,133	3,248	3,480	422	116	23	17	52	406	1,179
1880..........	232	441	696	4,582	5,104	6,090	2,726	348	29	17	12	290	1,714
1881..........	1,624	3,074	1,102	3,190	3,074	1,218	174	87	87	58	174	522	1,199
1882..........	523	522	1,740	2,320	4,524	2,900	696	580	52	232	100	100	1,191
1883..........	348	290	522	1,740	3,480	2,320	580	232	87	87	116	116	827
1884..........	145	1,740	3,480	3,480	2,900	2,320	2,320	580	116	87	....	....	....

The most important project in connection with irrigation in this county is the dam across American river, built by the Folsom Water Power Company at a point a short distance above the penitentiary. This structure is of the most substantial character, being built throughout of masonry. It was constructed through co-operation with the state authorities, by which convict labor was utilized. The main portion of the dam is 250 feet in length, and the greatest height is about 70 feet on the upstream side and nearly 100 on the downstream face. It is 24 feet in width on top and 87 at bottom. All parts of the structure have been designed to withstand the floods of the American river, these rising to heights of over 30 feet above the crest of the dam. On each side of the river are suitable headworks for canals, that on the right-hand or eastern side being completed. The works on the west side will probably not be undertaken for sometime, but the canal on the east, 50 feet wide on top, has been built to and beyond the penitentiary grounds. Water from this canal will be utilized for power and also for irrigation on lands south of American river. There are already small ditches covering a portion of this area, these being the property of the Natoma Water Company or of individuals.

SAN BENITO COUNTY lies southeasterly from San Francisco, comprising a portion of the long, narrow valleys between the two nearly parallel ranges west of Fresno and Merced counties. To the north is Santa Clara county, which extends also between mountain ranges to the bay of San Francisco. The greater part of the streams unite to form San Benito river, which, instead of continuing northerly through Santa Clara county, when near the northern county line turns abruptly and flows westerly into the bay of Monterey. The greater part of the surface of the county is undulating or mountainous, and the area of agricultural land is relatively small. The grazing upon the hill slopes is good and stock raising is an important industry, especially in the southern end of the county. Fruit raising is also profitably carried on, especially in the vicinity of San Juan, Hollister, and other towns. Irrigation is little practiced, since nearly all products are successful without the artificial application of water. Along San Benito river, however, and other streams a number of small irrigating ditches have been dug, these being usually from 1 to 2 miles in length. Water from artesian wells is also used to a small extent for fruit trees and alfalfa.

In the northern end of the county on the lower lands are a number of flowing wells, there being in all 117 enumerated upon farms in 1890. In depth these range from 29 to 329 feet, the average depth being 111 feet and the average cost $188. The artesian area appears to extend along San Felipe valley, wells being found upon both sides of the river, those on the north being in Santa Clara county. The quantity of water delivered by these wells fluctuates with the season, the flow being usually greater during a wet year. Only a small proportion of the water is used for alfalfa, fruits, and vegetables, the remainder flowing to waste.

SAN BERNARDINO COUNTY is in southern California, being separated from Mexico by San Diego county only. It extends from the Colorado river and the state line of Nevada on the east westward nearly to the Pacific ocean, at least at its southwestern corner. By far the greater part of the county is upon the Colorado or Mohave desert, the southwestern prolongation extending over the lofty mountains down into the valleys drained by the Santa Ana and other streams flowing to the sea. It is in this relatively small portion of the county that are concentrated nearly all the population and wealth of this the largest political division of the state.

This county contains some of the best examples of irrigation development to be found in the whole country. Although dealing with comparatively small quantities of water, these systems are notable for the elaboration of details and the care and expense lavished in saving and utilizing the water resources. There are to be found in the southwestern part of the county storage reservoirs, carefully built ditches, many of them paved and cemented, tunnels, flumes, pipes of cement, iron, and steel, many devices for measuring, dividing, and distributing the water; in short, examples of nearly every type of irrigation works, from the most crude to the latest improvements. In the point of cost and thoroughness of construction these works can best be compared with those built for municipal supply, some of the systems, though used for irrigation, being of the nature of city waterworks, bringing water under pressure both to the houses and to the orchards.

The high state of development of irrigation in San Bernardino and adjoining counties is due to the peculiarly favorable topography and the existence of physical features, duplicates of which can hardly be found in any other part of the United States. Two remarkably high and precipitous mountain ranges enter the southwestern part of the county from directions nearly at right angles to each other, and apparently culminate in the peaks northeasterly of the city of San Bernardino. The first of these, the Sierra Madre range, or San Bernardino mountains, has a general east and west trend through Los Angeles and Ventura counties, while coming up from the south are the San Jacinto and other mountains, trending in general parallel to the coast. The San Bernardino mountains have a height of from 6,000 to 7,000 feet, a few of the peaks rising to 9,000, 10,000, or even 11,000 feet and over in altitude. To the north and east of these stretches out the broad plain, broken by short ranges of mountains, among which the channel of the Mohave river meanders. The precipitation both of rain and snow upon these steep and lofty peaks is very great, giving rise to streams which flow down with rapid descent to the plains below. Each of these streams has cut for itself deep, narrow gashes, or canyons, in the mountain side, and the debris, consisting of sand, gravel, and bowlders, has been piled in great masses at the points where the streams enter upon the lower plains. A great part of the water, especially during the summer, disappears into these pervious deposits, to come to the surface again in springs, or cienegas, at lower points. These cienagas are found sometimes on or near the mesas bordering the valley or on the bottom lands, but wherever they occur they are of very great value, lands upon which they are situated being purchased at enormous cost.

Among the high peaks are open valleys, several of which have a topography favorable for the construction of reservoirs, in which can be held the water from rain and melting snows. The waters thus held can be discharged into the stream channels and to a large extent recovered at points of diversion below. Much of the water which sinks into the gravel or bowlder channels of the streams can be or has been brought out by means of tunnels driven into the steeply sloping beds until solid rock is reached, the percolating waters being intercepted in this manner.

The water thus obtained from the surface streams, from storage reservoirs, tunnels, springs, and artesian wells is conducted by open channels, flumes, and pipes to the rich mesa and valley lands, the systems of distribution being in the aggregate exceedingly complicated, sometimes crossing and recrossing, water from one side of the valley being brought to the other and lands in the vicinity of one source of supply being covered by water from a distant locality. This is the result that might be expected from the gradual evolution of crude methods of irrigation and the growth without plan or system, adding a piece here, reconstructing there, and compromising quarrels or difficulties in the manner that at the time seemed best or easiest. All of these facts, as well as the physical features, have been so graphically described by the state engineer (*a*) and shown in such detail on the irrigation sheets prepared by him that it seems unnecessary to enter further into them. (*b*)

---

[a] Irrigation in Southern California, by William Ham. Hall, C. E.

[b] The county and its irrigation works have also been described by F. C. Finkle, C. E., in the Engineering News. Irrigation and Irrigation Districts in San Bernardino County, California. Engineering News and American Railway Journal, New York, 1891, volume 26, pages 2, 75, 76, 171, 172, 182, 183.

By bringing water upon the mesas or benches which lie along the foot of the mountains large areas of this fertile land have become of extraordinary value, advancing from a few dollars to several hundred per acre, the expenditure for water supply being but a small fraction of its present worth. The soil on these mesas varies greatly, but much of it is well adapted to the cultivation of citrus fruits, to which also the climate and other influences are peculiarly favorable. Many thousand orange and lemon trees have been cultivated with success, as well as olives, grapes, and the so-called deciduous fruits. Under favorable circumstances the product per acre has been marvelous, reaching $1,000 or more. Such profits, both in the increase of land values and in the annual productions, justify extraordinary expenditures in the conservation of water even to an extent far greater than now practiced. Progress is being made in this direction not only by the water companies but also by the formation of irrigation districts, which either develop their own source of supply or purchase a stated quantity of water from companies already formed.

In order to increase the efficiency of the supply and to prevent loss of water in distribution many of the ditch owners have made decided improvements in the methods of conducting and distributing the water. The old open channels have in many cases been lined with cement or replaced in part by pipes of iron, steel, earthenware, or wood, and every precaution has been taken to prevent waste, thus tending to raise the water duty to an amount higher than that obtained in other parts of the arid region. As a rule it may be said that water is too valuable to be used upon any but the higher class of fruits and vegetables. Nearly all of the cereals are grown upon the lands of the San Bernardino valley and along the Santa Ana river without irrigation, the average production being relatively small.

There is as great diversity in the methods of distributing water as in its ownership. Under perhaps the best system water is piped, under pressure, to each small tract and can be drawn from a hydrant at the pleasure of the irrigator, he paying a certain rate per year. In this way probably the greatest economy of water and time is insured, for the right quantity can be applied to the ground at the proper moment. Under other systems the owner of a share in a ditch or pipe line receives the whole flow for so many hours or minutes, depending upon his proportion to the total ownership. In this case he must be ready at any time, day or night, to apply the water to the ground, or else lose his turn. To obviate the inconvenience and loss, as, for instance, at night, working by the light of a lantern, neighboring irrigators sometimes make arrangements to "pool" together and rearrange the time to suit themselves, or if a man can afford it he constructs a small reservoir to hold his share of the water until needed. Under still other systems the irrigator receives a constant small stream of water day and night, and this to be advantageously used must be received in cement tanks or reservoirs until sufficient has accumulated to flow readily over the dry ground. Many of the water companies, irrigation districts, or associations of land owners own stock or have partnership arrangements with other corporations, so that the business relations, as well as the irrigation works, are somewhat complicated and can not be made plain in a brief description. These purchases of stock and interrelations have grown up from compromises made in settlement of disputes, which in some cases have cost more than the construction of the works themselves.

The quantities of water handled by the different companies in this county are small relative to those carried by the great ditches of other parts of the state, as, for example, those of Kern county. There have been but few measurements made of streams in this county, but these will serve to show the size of the principal ones. The following table of the mean daily discharge of the Santa Ana river is taken from the report of the state engineer (*a*), the quantities being converted into second-feet. It should be noted that the discharge in these years was regarded as exceptionally small. (*b*)

MEAN DAILY DISCHARGE OF SANTA ANA RIVER AT THE POINT WHERE IT LEAVES THE MOUNTAINS.

MONTHS.	1881	1882	1883	MONTHS.	1881	1882	1883
May	24	24	24	September	16	13	13
June	22	23	23	October	20	17	17
July	20	18	18	November	22	21	21
August	14	13	13	December	22	22	22

---

a Irrigation in Southern California. William Ham. Hall, C. E., page 191.

b The maximum and minimum discharges of Lytle creek, as observed by F. C. Finkle, C. E., at the mouth of the canyon are as follows:

YEARS.	DISCHARGE IN SECOND-FEET.		YEARS.	DISCHARGE IN SECOND-FEET.	
	Minimum.	Maximum.		Minimum.	Maximum.
1887	14.83	1,842	1890	23.46	2,752
1888	18.67	2,231	1891	18.21	3,179
1889	17.39	2,113	1892	13.73	893

The minimum discharges occur in August or September and the maximum discharges in January or February.

In San Bernardino county in 1890 there were enumerated as being on farms 301 artesian wells, ranging from 65 to 700 feet in depth, and having an average discharge of 283 gallons per minute. The water of many of the larger of these wells is piped to the various towns, giving them an ample supply of clear, pure water. A few of the wells are used for purposes of irrigation, an average of 20 acres being watered to each well thus employed. A large number of wells have been put down by land companies in order to ascertain the extent and amount of the artesian supply, and the resources of the county in this direction are quite well explored. A few of the farmers complain that these large wells, which have been allowed to flow freely for months or years, have resulted in the drying up of the shallow wells near the edge of the basin.

The following list, prepared in 1890, gives the names of the principal irrigating systems, together with the total area which it was estimated could be irrigated by each at that time:

	Acres.		Acres.
Total	144,750	Mill creek	5,000
Riverside	10,000	North Riverside canal	10,000
Gage canal	15,000	Vivienda pipe line	5,000
South Riverside	6,000	Rincon ditch	4,000
Pomona	12,000	Chino pipe line	2,500
Ontario	5,000	City creek	500
Etiwanda	3,200	Twin creeks	3,000
Cucamonga	10,000	Banning	4,800
Lytle creek	15,000	Colton Terrace	1,500
North Fork ditch	4,000	Bear Valley reservoir	18,000
South Fork ditch	4,000	Glen Ellen	2,000
		Meeks and Daly ditch	4,250

The list given above comprises only the more important systems of water supply, there being others in operation or under construction which might properly be mentioned. In attempting to describe even in a brief way the irrigation works of San Bernardino county a compiler is presented with such a mass of facts and statistics that it seems impossible in the space alloted to do justice to the various systems. An attempt is made, however, to describe some of the more novel features, especially in connection with the utilization of storage reservoirs and artesian wells. These matters are taken up in a general geographic order, beginning with the works of the Bear Valley Company, on the head waters of Santa Ana river. On the south side of this river the principal works mentioned are the Gage, Riverside, and South Riverside canals, and on the north or left hand bank the North Riverside and Jurupa. Brief mention is also made of some of the irrigating systems receiving water from the canyons on the north side of the valley, namely, the Rialto, Semi-Tropic, and Etiwonda, and of the Arrowhead storage scheme, whose reservoirs, high in the mountains, will probably supply water to this part of the county.

The irrigation system most widely known is that of the Bear Valley Company, taking its name from that of its reservoir, located in the high mountains northeast of San Bernardino. This company has not only constructed one of the largest reservoirs in the country but has other projects for saving water and for distributing it widely over the country to the south and west. It appears that the principal part of the business of this company consists not in selling water to individual consumers but in disposing of it in large quantities to other water companies or to irrigation districts, who in turn apportion the water to the consumers. The water is obtained by the company not only by storage in Bear Valley reservoir but also to some extent from the flow of surface streams and from tunnels and wells. Efforts are being constantly made to increase these sources in number and in availability, the works being extended from time to time.

The Bear Valley reservoir has been formed by placing a dam across the outlet of a high mountain valley about 20 miles northeasterly from the city of San Bernardino. This valley is described by the state engineer as being a remarkably large and flat mountain basin lying at an altitude of from 6,200 to 6,300 feet above the sea. Out of its western extremity is a deep gorge cutting southerly, allowing the waters from this valley to flow into Santa Ana river. The bottom of the valley is about 12 miles long and from an eighth of a mile to a mile in width. A dam 120 feet high would create here a pond over 11 miles long, submerging a little less than 8,000 acres. The catchment area tributary to this valley is less than 45 miles in extent, and for the most part is steep and heavily timbered. The precipitation is very large, owing to the peculiar topography. The dam built by the Bear Valley Company is remarkable, from the fact that it consists of a stone wall, curving up stream, and held from being overturned by the water above it by the arched form. Its extreme height is 64 feet, length at top 300 feet, thickness at top 3 feet, and at 48 feet below the top only 8.5 feet. In spite of many predictions to the contrary this dam has stood, but in order to increase the storage capacity and for other reasons the company has decided to construct a new masonry dam below the first, and one which does not depend upon the principle of the arch to hold its place. The areas and capacity of the reservoir at different elevations are shown by the table on the following page. (*a*)

---

[a] Irrigation in Southern California. William Ham. Hall, page 182.

ELEVATIONS OF WATER PLANE.		Corresponding areas of reservoir surface. (Acres.)	CAPACITIES OF RESERVOIR: TOTALS ABOVE GROUND SURFACE.	
Above base of dam. (Feet.)	Above outlet. (Feet.)		Cubic feet.	Gallons.
10	0	4.95	637,000	4,000,000.72
20	10	34.93	6,921,900	51,000,000.78
30	20	294.54	67,850,660	507,000,060.52
40	30	1,060.01	312,153,521	2,334,000,000.91
50	40	1,691.41	920,824,487	6,887,000,000.77
60	50	2,251.50	1,763,166,320	13,188,000,000.38
70	60	2,812.00	2,834,253,750	21,199,000,000.22
80	70	3,300.00	4,161,190,000	31,125,000,000.70

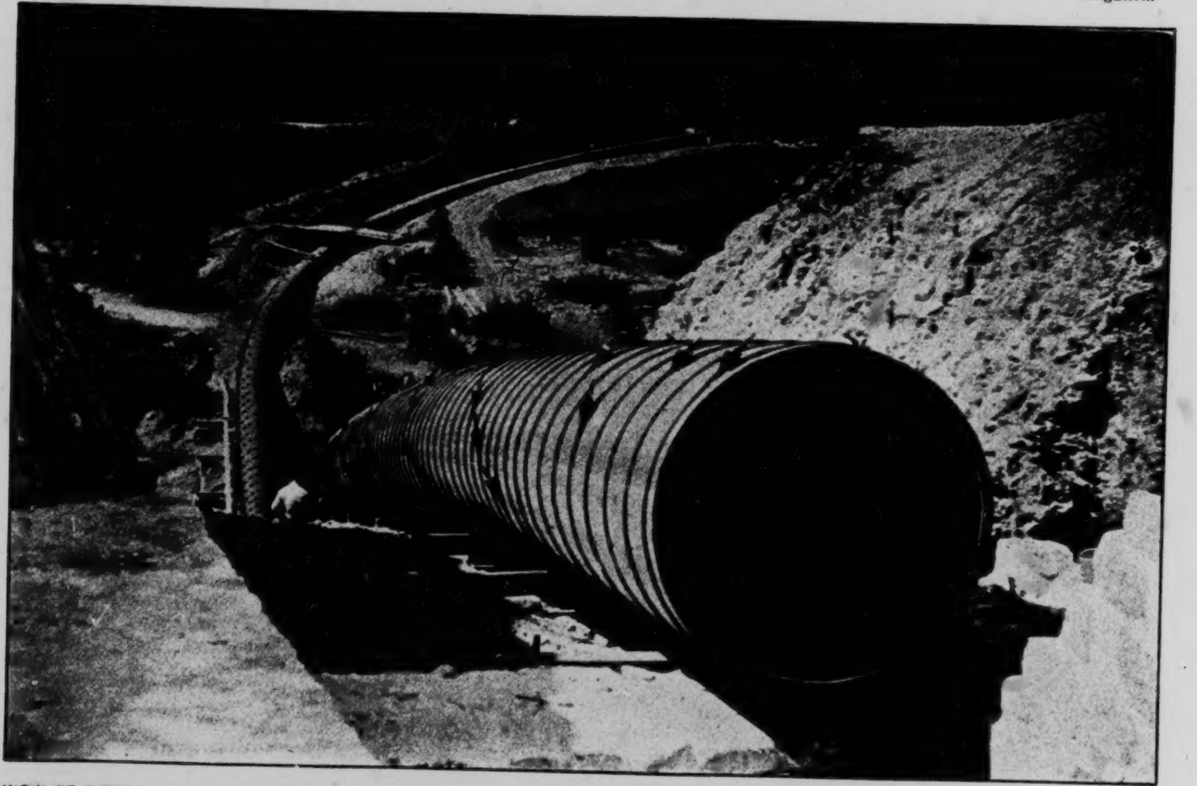
The dam cost upward of $75,000, a sum largely in excess of what it would have cost had it not been for the great difficulties of transportation between this point and the lower valleys. From the reservoir the waters flow down Bear creek to the Santa Ana river and are diverted by ditches owned by the Bear Valley Company acting in co-operation with other companies. These ditches carry the water out on the north and south sides of the river and in turn deliver it to irrigators' ditches and to pipe lines owned by the various water companies or irrigation districts. In the case of the Alessandro and certain other districts the company agrees to deliver a supply of water sufficient for the irrigation of all lands, this being estimated to be at the rate of 1 miner's inch to each 4 acres, or 1 second-foot to 200 acres, a water right larger than possessed by many irrigators. Each certificate issued entitles the owner to 1 acre-foot of water per year upon the payment of $1.39 on the 1st of April, and $1.39 on the 1st of October of each year, the water being delivered in general at the times and in the quantities desired by the user. The reservoir company issues two classes of water certificates, known respectively as A and B. Of class A, there were issued on June 1, 1886, 7,200 certificates on the basis of 1 miner's inch to 7 acres. The water called for by these must be used for irrigating lands in Redlands, Lugonia, Mound City, Highlands, and vicinity. The certificates of class B, mentioned above, have been sold in part to the Perris, Alessandro, and other irrigation districts.

The property of the Bear Valley Company consists, besides the reservoir, of a half interest in the North Fork canal, the canal on the south side of the river, the pipe line to the Crafton reservoir, the pipe line to the Alessandro and Perris districts, and other lines and distributing systems. The pipe line to the Alessandro tract after passing by a tunnel through the San Timoteo hills has a fall of about 300 feet, furnishing a water power of great value.

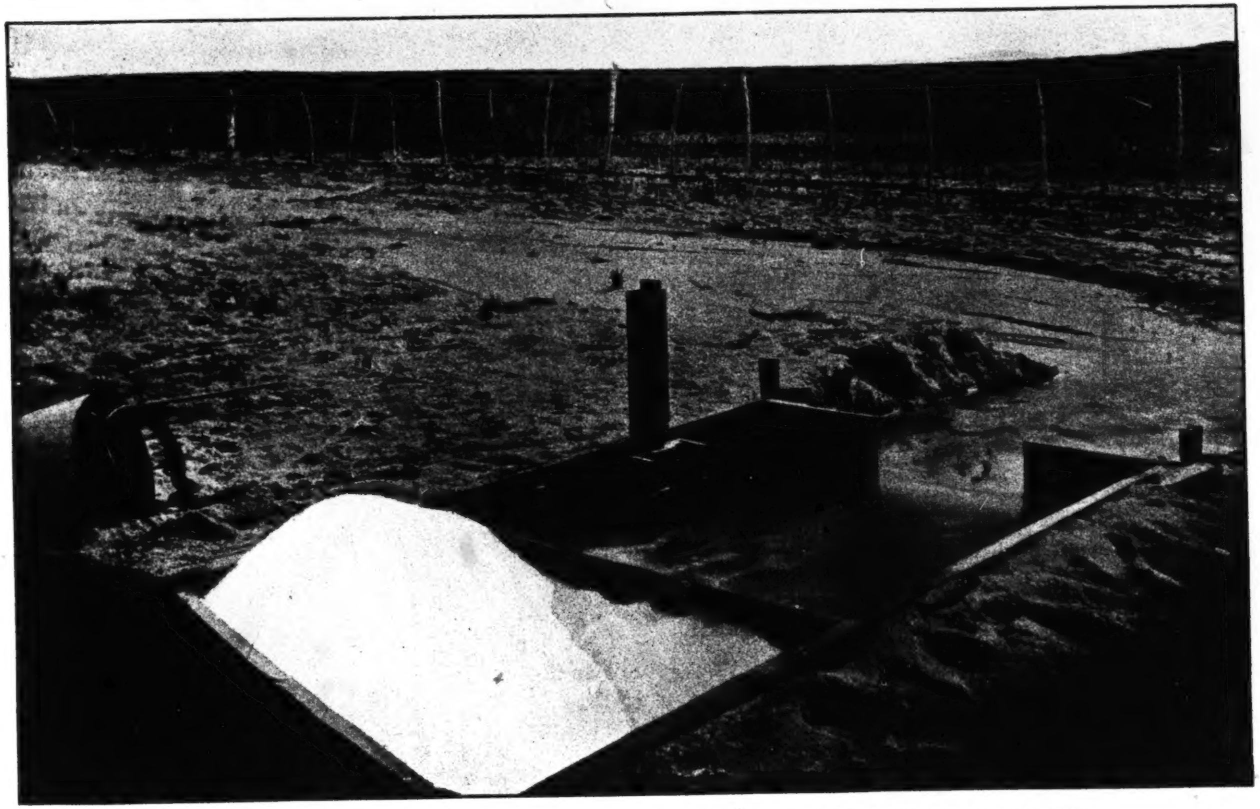
The irrigating system of the Gage canal is remarkable in many ways, and not the least of these is the method of obtaining water. The greater part of the supply is had from 51 artesian wells, whose aggregate discharge was found to be 1,793.45 miner's inches, or, at 50 inches to the second-foot, 35.87 second-feet. In addition, water is obtained from the Santa Ana river, so that the canal company has a minimum supply in all of something over 42 second-feet. The artesian area extends along the Santa Ana river, embracing a considerable tract of land located at from 2 to 3 miles southeasterly from San Bernardino. The wells are widely distributed, but in general extend for a distance of 3 miles along the upper part of the canal and in the river bottom.

GAGE ARTESIAN WELLS—DEPTH AND CAPACITY.

NUMBER OF WELL.	Distance apart in feet.	Depth in feet.	Pressure in feet.	Capacity in miner's inches.	NUMBER OF WELL.	Distance apart in feet.	Depth in feet.	Pressure in feet.	Capacity in miner's inches.
Total				1,793.45	26	280	123	13	21.00
					27	320	125	14	9.00
1	0	656	25	5.00	28	280	144	15	38.00
2	1,216	534	70	32.50	29	310	140	16	28.35
3	296	382	76	29.00	30	790	138	13	11.25
4	525	482	74	41.25	31	430	106	15	8.75
5	561	320	23	3.50	32	35	130	16	16.25
6	265	784	80	45.00	33	315	146	18	41.00
7	4,620	196	11	13.75	34	550	116	16	48.00
8	353	190	11	21.00	35	130	134	15	30.50
9	204	142	11	3.50	36	120	116	16	16.00
10	320	148	12	3.25	37	680	147	16	43.00
11	714	141	28	24.50	38	90	122	16	28.75
12	80	181	29	21.62	39	276	115	17	10.50
13	765	426	16	86.50	40	1,090	109	17	77.15
14	530	472	17	101.50	41	474	193	14	63.50
15	1,680	518	17	62.50	42	510	192	17	85.75
16	190	388	50	50.00	43	510	390	18	109.75
17	175	380	50	32.00	44	500	224	20	92.75
18	480	386	50	27.00	45	1,580	123	25	70.50
19	330	196	17	43.50	46	15	133	25	6.70
20	270	124	12	9.50	47	15	133	25	24.40
21	260	116	13	24.75	48	40	139	25	29.33
22	270	134	17	50,50	49	50	211	23	28.40
23	265	168	11	86.00	50	40	100	25	15.00
24	285	166	14	26.00	51	1,590	300	22	80.06
25	320	152	14	19.75					



VIEW OF FIFTY-TWO-INCH REDWOOD PIPE, CROSSING WARM SPRINGS CREEK NEAR REDLANDS, SAN BERNARDINO COUNTY, CALIFORNIA, ON THE MAIN HIGH LINE OF THE BEAR VALLEY CANAL.



VIEW OF ARTESIAN WELL AND MEASURING DEVICE. GAGE SYSTEM, SAN BERNARDINO COUNTY, CALIFORNIA.

The figures given in the preceding table were obtained from the engineer of the company, who states that measurements of discharge were taken at the end of the irrigating season while all the wells were open and after they had been flowing freely during the summer. The pressure in feet was taken of each well while it was closed. The accompanying illustration gives a near view of one of these wells and shows the method of measuring the discharge. At the left the water is seen flowing over the top of the pipe and falling into a small wooden compartment. From this it passes through a screen made of wooden slats into the second compartment, the object of the screen or partition being to break and diffuse the motion of the water. On the far side of the second compartment is an opening, the edge of which is covered by a metal plate accurately placed so as to form a weir. At one side is a small chamber, and in this is placed the hook gauge for measuring the height of water.

All the wells are put down by means of a sand pump, which works inside of a double thick iron casing, this casing being forced down by means of hydraulic jacks. The sand pump consists of a tube with a valve at the bottom so arranged that sand and small gravel can enter freely. When the sand pump is lifted the valve closes and the sand and gravel are brought to the surface. As the material is thus excavated the casing or lining of the well is forced farther and farther down. This lining is made of two thicknesses of sheet iron of No. 10 or 12 gauge and consists of sections 2 feet in length. The inside and outside lengths are inserted alternately, the joints of an outside pair coming opposite the middle of an inside piece and vice versa. The casing is thus practically continuous and after being put in place soon becomes perfectly tight.

Water from the river is diverted by means of temporary brush and sand dams renewed each year, the expense of so doing being less than the probable interest and cost of maintenance for more permanent works, since the channel of the stream is composed of shifting sands and of other unstable material. The flood discharge at times reaches 2,000 second-feet or over, this quantity quickly diminishing to medium or low stages, at which time all the water in the river can, if necessary, be diverted into the canal by quickly throwing up a small embankment of sand. The total length of the canal is a little over 20 miles, and throughout the greater part of the line it has been excavated, generally in clay, to a depth of 4 feet, and on a grade of from 2 to 3 feet per mile. Work was begun in 1885, and construction was practically completed in 1888. Since that time, however, many improvements and alterations have been made.

For the greater part of its length the canal is lined with masonry, which in all tunnels and fills is 5 inches thick, this being covered with cement mortar. The remaining portions are lined with cement plaster having a thickness of three-fourths of an inch. The aggregate length of the tunnels is very nearly one mile, and of the flumes three-fourths of a mile.

From the canal water is distributed by means of pipes located at convenient intervals. Water is admitted to these by means of metal valves inserted in brick bulkheads. In each of these bulkheads is a small measuring weir, so that the amount diverted at each point can be accurately ascertained. The steel pipes traverse the streets of the towns under the canal and are provided with lateral connections to each lot, water being thus carried to a hydrant located at the highest point of 10-acre subdivisions. The water from the hydrants can then be conducted in small open flumes to the irrigating furrows. The whole distributing system is under control of an officer charged with the duty of subdividing the water to the several owners in accordance with the number of shares held by each. The duty of the water is stated to be at the rate of 5 acres to the miner's inch, or 250 acres to the second-foot. Each purchaser of land under this system becomes a shareholder in the canal and can participate to the extent of his ownership in the management of the company. The lands supplied are mainly those included in what are known as East Riverside and Arlington Heights.

The Riverside irrigating system, constructed before the Gage canal, covers lower lands near the river. It comprises two canals, in a general way parallel to the Gage, and known respectively as the upper and lower, both of these taking water from the Santa Ana river. Water is diverted by means of brush dams, which are liable to be washed out during heavy floods. This comparatively crude method has been followed because the Santa Ana river in this portion of its course has a wide sandy channel which shifts and washes out in times of flood. It is therefore cheaper to build temporary dams than to pay the interest on large and elaborate headworks whose stability might be questionable. The supply is increased also by waters from Warm creek and from artesian wells. At one point on the upper canal is a drop of 40 feet, the water power being used to develop electricity. This is conducted a distance of 8 miles to the city of San Bernardino. Under these canals are some of the oldest and most noted orange groves of southern California, the returns from which have attracted much attention in all parts of the United States. The total cost of the Riverside canal and distribution system is estimated to have been about $375,000.

The South Riverside system, consisting mainly of pipe lines, covers land southwesterly from Riverside. The supply is obtained by collecting water from a number of small canyons in the Temescal mountains, by draining cienegas and by sinking artesian wells, in all the quantity being estimated at about 23 second-feet. This, or at least the greater part of it, is conducted by means of a cement pipe 30 inches in diameter and about 9 miles in length. The water is distributed by means of pipes of various sizes to the town of South Riverside and to adjacent property. Efforts are being made to increase the amount of water available by means of a dam in the Temescal canyon where bed rock approaches the surface. The dam, if constructed to the height of 50 or 60 feet, will flood an area of several square miles. It is estimated that the system has cost on an average $40 per acre irrigated, while the present value is upward of $100 or even $200 per acre. The statement is made that $1.25 per acre will cover the annual expenditures. The Jurupa canal is on the north side of Santa Ana river northerly from Riverside. It obtains water from Warm creek and the Santa Ana river and from a cienega developed by means of a deep cut in which has been placed a redwood drain. From the cienega the canal is in all 18 miles in length, water being carried across the Santa Ana river on a trestle flume.

The irrigating works of the Semi-Tropic Land and Water Company of Rialto are located south of Lytle creek canyon and consist of about 5 miles of cement ditch, costing $40,000, and capable of carrying 3,000 miner's inches. The artesian wells furnish from about 600 to 800 miner's inches of water and the surface developments about 500 miner's inches additional. The distributing system consists of 55 miles of cement pipe of various dimensions. The total cost of the works when completed will be in the neighborhood of $250,000, the water development costing about $75,000. It is proposed to increase the water supply and bring the so-called "underflow" in Lytle creek canyon to the surface by means of a submerged dam placed in the canyon.

The Etiwanda Water Company obtains water from the Day and Young canyons, carrying it out by means of a V-shaped flume which cost probably about $5,000. The flume is made of redwood plank, the sides being 18 inches wide, and the total length is 4 miles. The water flows first to a sand box and then to a small reservoir about 20 feet square. From this it is distributed to 8 concrete pipes, each of from 6 to 8 inches in diameter. These carry the water to the highest portion of each 10-acre lot. To each of these 10-acre pieces 37.5 miner's inches for 24 hours is given at intervals of 30 days. The value of the land with water is placed at from $150 to $200 per acre and the annual expense about $1 per acre. Of the 1,000 acres supplied by this flume about 750 acres are planted with raisin grapes, 100 acres with deciduous fruits, and 150 acres with citrus fruits. The land cost the present owners about $25 per acre. Irrigation is practiced generally in June, July, and August, the ground being continually cultivated at short intervals throughout the year. For raisin grapes in bearing only two irrigations per season have been given, the young vineyards receiving three or four. The deciduous and citrus fruit trees are watered from three to six times.

The Arrowhead Reservoir Company proposes to construct three reservoirs on the north side of the San Bernardino range, each of these to be filled by canals taking water from streams tributary to the Mohave river, the principal of these being Deep creek. If constructed according to the plans, the reservoir in Little Bear valley will hold 22,000,000,000 gallons, that in Grass valley 10,000,000,000 gallons, and that in Huston Flat 6,000,000,000 gallons. The Hesperia Land and Water Company, whose works are on the north side of San Bernardino range, takes water from the Hesperia or east fork of the Mohave river by means of a ditch and pipes, the total cost of the system being estimated to have been $150,000. The ditch is about 4 miles in length, and for a great part of the way was built through the rocky walls bounding the river. From its lower end the pipe line, 14 inches in diameter, descends to and across the river and up on the opposite side, the pressure at the lowest point being, it is stated, over 176 pounds to the square inch. The water is conducted to the vicinity of the town of Hesperia, a station on the California Southern railroad about one-third of the distance from San Bernardino to Barstow.

In this county 7 irrigation districts have been formed, namely, the Alessandro, Citrus Belt, East Riverside, Grapeland, Olive, Rialto, and Riverside Heights. The Alessandro district is outside of the San Bernardino valley proper, being separated from it by the San Jacinto hills. It adjoins on the south the Perris district, in San Diego county. Water for both of these districts is obtained by purchase from the Bear Valley company, being conducted from the Santa Ana river at the point where it leaves the mountains by means of a steel pipe line 10 miles in length and 24 inches in diameter. From this main pipe line water will be distributed to each 10-acre lot by means of vitrified and cemented pipes. The lands in this district are owned mainly by the Bear Valley Company, who sell the lots, together with a water supply, the annual rate for this being $2.78 per acre. The total area of the district is 25,500 acres and the assessed valuation $2,493,000. The district is bonded to the extent of $765,000, all of the bonds being taken by the Bear Valley Company in consideration of furnishing a water supply.

The Citrus Belt district, comprising 12,000 acres, is between Etiwanda and Rialto. The assessed valuation is $622,722, and bonds to the amount of $800,000 have been voted. It is proposed to obtain water from artesian wells or from other sources, possibly by purchase from some large storage company. The East Riverside district, comprising 3,600 acres above the town of Riverside, is to be irrigated by means of artesian wells, the water being conveyed to each 40-acre lot by iron pipes, at an estimated cost of $250,000. Bonds to this amount have been voted, and of these a portion have been sold for cash. The Grapeland district is northwest of Rialto and on the west side of Lytle creek. Water is to be obtained by means of a tunnel driven beneath the bed of Lytle creek and possibly from other sources. In order to carry out this work bonds to the amount of $200,000 have been voted. (*a*) The Olive district comprises a relatively small area, 1,280 acres, on the north side of Santa Ana river west of Colton and contiguous to the Citrus Belt and Rialto districts. It is proposed to obtain water from artesian wells, from Lytle creek, or possibly from the Arrowhead system.

---

[a] For details concerning the East Riverside and Grapeland districts refer to reports of the chief engineer, F. C. Finkle. Reports of officers of the East Riverside irrigation district, San Bernardino county, California; pamphlet, 48 pages. Also chief engineer's report on the Grapeland irrigation district, 1892; pamphlet, 58 pages.

The Rialto district is southwest of the town of that name and consists of 7,200 acres, whose assessed valuation is $534,360. Bonds to the amount of $500,000 have been voted in order to obtain a water supply, to be derived from artesian wells in Lytle creek basin and to be distributed by means of cement ditches and pipes. Riverside Heights district, including 3,500 acres, has been formed for the purpose of obtaining a water supply, if possible, from Box springs or from artesian wells, or by means of a tunnel to bring out the ground waters.

SAN DIEGO COUNTY occupies the extreme southern end of the state of California, extending from the Colorado river on the east to the Pacific ocean on the west. The description of this county given in the report upon irrigation in southern California (*a*) is so complete that little more need be said. Within the western valleys and in places upon the mesas agriculture has been practiced for many years, crops being raised by dependence upon the rainfall. Large areas of small grains are cultivated in this manner, the yield per acre being somewhat small. The orchards and vineyards also in many places are fairly successful without artificial watering, but the most profitable of these are under irrigation. The reputation of this county as a fruit producing area rests almost entirely upon the irrigated orchards and vineyards, and it is often a matter of surprise to strangers to find that there are large areas upon which fruit is raised every year without moisture artificially applied. Indeed in several of the valleys, for instance, that of El Cajon, the inhabitants have regarded it almost as an insult to intimate that it was necessary to irrigate the vineyards. Experience has shown, however, that by employing water at suitable times the raisin crop can be doubled or even trebled, the yield increasing from $50 or $60 per acre to $150 or $200 in value.

The general appreciation of the value of irrigation, even on lands on which crops can be raised by dependence upon the rainfall, is perhaps best shown by the increase in selling value after a system of water supply has been established. Taking the ordinary farming land, whose value averaged $15 per acre, it has been found that the average cost of bringing water to this has been $25 per acre, and the cost of cultivation, not including the setting out of an orchard or vineyard, $30 per acre, making a total of $70. Such land has sold for from $100 to $200 or more per acre. It may be stated here that the attempt to ascertain average values of farm land in this and other counties of southern California is rendered difficult by the fact that there are relatively few farms in the sense that the word is used in other parts of the United States. A great part of the lands under irrigation have been subdivided into small tracts of from 5 to 10 acres, each of these being designed as a place of residence as well as a source of income from horticulture and small farming. Many improvements have been made upon or near these tracts, and thus the land has acquired a value dependent largely upon what may be called its suburban character. The statistics from these small farms thus have a peculiar influence upon the general agricultural results for the state.

When this land has been set with orchards and vineyards its value is placed at from $1,000 to $1,500 or more per acre, dependent upon its location, the character of the trees and vines, and surrounding circumstances. The production per acre from some of these tracts almost surpasses belief. In favorable situations in the county all the fruits of the semitropic and temperate zones reach extraordinary development.

As previously stated, many of these fruits, as, for example, grapes, apples, olives, peaches, and apricots, are often successful without irrigation, and many of the fruit growers still insist that in the case of grapes, for example, the quality is better although the quantity is less. It has been stated that in raisin making there is less contrast than might be expected between the irrigated and nonirrigated vineyards, for although the yield of grapes raised by artificial watering is far heavier, yet after drying the difference is not as marked. Wheat and barley also, according to some farmers, make a better hay when cultivated without artificial watering, but the weight is less. Shade trees, such for example, as the eucalyptus or Australian blue-gum, the catalpa, mulberry, and acacia, grow well without water, but do not reach the extraordinary development that they do when near irrigating ditches. It is almost useless to attempt to raise the citrus fruits without plenty of water. The quantity actually employed varies greatly, but in a general way it may be said that alfalfa receives sufficient water during the year in the aggregate to flood the ground to a depth of from 2 to 3 feet, while the vineyards and orchards receive in all perhaps a fifth or even a tenth of this.

The quantity of water necessary to irrigate an acre as estimated by the different companies ranges from 1 miner's inch to 5 acres to 1 miner's inch to 20 acres, the miner's inch in this county being defined as a quantity equaling 12,960 gallons in 24 hours, or almost exactly 0.02 second-foot, this being the amount which has been delivered under a 4-inch head, measured from the center of the opening. Under this assumption 1 second-foot should irrigate from 250 to 1,000 acres. This is on the basis of delivering the water in pipes or cemented channels in the immediate vicinity of the trees or vines to be irrigated. If it is assumed that 1 miner's inch is allowed for 10 acres, or 1 second-foot for 500 acres, this quantity of water flowing from May to October, inclusive, will cover the ground to a depth of a little over seven-tenths of a foot, or 8.8 inches, a quantity which with the care and cultivation usually employed has been found to be sufficient. The method of applying water governs to some extent the amount used. In the case of alfalfa flooding is practiced; with small grains the water is run in furrows, while in the case of orchards the water is sometimes applied directly to each tree. In this case a little earth basin

---

[a] Irrigation in California, Southern. The field, water supply, and works, organization and operation in San Diego, San Bernardino, and Los Angeles counties. The second part of the report of the state engineer of California on irrigation and the irrigation question. Wm. Ham. Hall, C. E., state engineer. Sacramento. 1888.

about 6 feet or more across and 6 inches deep is formed around each tree and partially filled with water. The better way, however, is probably that of running water in furrows, four or five of these being plowed between each two rows of trees. The water is applied very slowly, several days being spent in watering 5 acres, and when dry the ground is thoroughly cultivated.

The first cost of water or of water rights where these have been sold independent of the land has been from $15 to $25 per acre, while subsequent transfers have been made for far larger sums. The annual charges when by the acre have been as low as $3, and from this rising to $6 or more per acre. In the case of the San Diego Flume Company it is stated that water was sold for $600 per miner's inch, with an annual charge or rental of $60, 1 miner's inch being considered sufficient for from 10 to 20 acres, depending upon the soil and growth. The annual charge for water from the Sweetwater system (San Diego Land and Town Company) was for orchards $3.50 per acre.

The chief water supply for the western part of San Diego county is derived from the Tia Juana, Otay, Sweetwater, San Diego, San Dieguito, San Luis Rey, Santa Margarita, and San Jacinto rivers. Systematic measurements of the discharge of these streams have not been carried on for any considerable length of time, but the state engineer estimated that the Sweetwater discharged at its maximum 1,000 second-feet, dwindling in dry weather almost or quite to nothing. The San Diego may reach 1,000 second-feet or even 2,000 second-feet for a few days, quickly falling to less than 100 second-feet. The San Luis Rey, with its relatively large and high watershed, probably delivers the largest quantity of water and with fluctuations somewhat less than the other streams. The Santa Margarita or Temecula possibly reached 5,000 second-feet in the great flood of 1884–1885, while its ordinary winter flow is from 600 to 800 second-feet, dropping to from 2 to 4 second-feet in the dryest season. The San Jacinto reaches a maximum of from 2,000 to 4,000 second-feet in winter and probably flows never less than from 6 to 8 second-feet through its rocky channel.

Along the San Diego, Santa Margarita, San Jacinto, and a few other streams are a few open ditches comparable to those used in other parts of the arid region, but these are old and may be considered exceptional to the general methods of irrigation. The important systems of the county are those in which water is conducted by flumes or pipes, dependence being placed upon reservoirs for permanence of supply. The best known of these is that constructed by the San Diego Land and Town Company, commonly known as the Sweetwater system, from the reservoir and dam of that name. This is located about 8 miles easterly from San Diego. It has been fully described by the state engineer, so that at this time it is essential to give only a few figures to serve for comparison with other projects. As published by the company the principal dimensions are as follows: length at base, 76 feet; length at top, 396 feet; thickness at base, 46 feet; thickness at top, 12 feet. The dam is built of granite and Portland cement. It was commenced in November, 1886, and completed in April, 1888, at a cost in round numbers of $200,000. The reservoir covers about 700 acres and has a capacity of 6,000,000,000 gallons. The area and capacity at various levels are shown by the following table:

AREA AND CAPACITY OF SWEETWATER RESERVOIR AT DIFFERENT LEVELS.

ELEVATIONS OF WATER PLANE.		Corresponding areas, reservoir surface. (Acres.)	CAPACITIES OF RESERVOIR ABOVE LOWEST WORKING OUTLET.	
Above sea level. (Feet.)	Above lowest working outlet. (Feet.)		Gallons.	Cubic feet.
150	5	10.72	11,000,000.64	1,556,000
160	15	43.10	79,000,000.62	10,643,000
170	25	113.40	329,000,000.45	44,044,000
180	35	200.77	835,000,000.95	111,758,000
190	45	326.96	1,710,000,000.58	228,687,000
200	55	463.80	3,005,000,000.64	401,823,000
210	65	630.94	4,778,000,000.54	638,842,000

The San Diego Flume Company's enterprise is another notable feature of irrigation in this county. The system embraces a number of projects and is by no means fully complete in all its parts. The main reservoir now constructed is that known as the Cuyamaca, about 43 miles northeast of San Diego in the Cuyamaca mountains, and at an altitude of 4,500 feet above sea level. The record of rainfall for that locality begins July 1, 1887, and is as follows: (*a*)

	INCHES.
1887-1888	22.00
1888-1889	52.65
1889-1890	61.51

---

[a] The following is the record since 1890:

	INCHES.
1890-1891	63.76
1891-1892	39.61

There has been ample water to fill the reservoir each year. The dam is of earth and is 635 feet long on top and 40 feet in height. The capacity of the reservoir is a little over one-half that of the Sweetwater, its contents at various heights being shown by the following table, also from the state engineer's report:

CAPACITY OF CUYAMACA RESERVOIR AT DIFFERENT LEVELS.

HEIGHTS.	Gallons.	Cubic feet.
5 feet above outlet	0.11	15,060
10 feet above outlet	5,000,000.04	675,065
15 feet above outlet	126,000,000.54	16,917,400
20 feet above outlet	523,000,000.15	69,940,300
25 feet above outlet	1,262,000,000.10	168,730,200
30 feet above outlet	2,342,000,000.28	313,139,300
35 feet above outlet	3,739,000,000.11	499,880,930

The water of the San Diego river supplies the flume until April or May, when the reservoir is drawn upon. The water from this flows down Bowlder creek for about 12 miles, and, as in the case of the river, water is diverted into the flume by a masonry dam 30 feet high and 450 feet long. The flume itself is 6 feet wide by 4 feet deep, built of redwood plank, and has a total length of 35.9 miles, with a grade of 4.75 feet per mile. There are 8 tunnels on the line, with an aggregate length of 4,168 feet, and at several points the flume passes over high trestles. Water is delivered at points along the line, for example, in El Cajon valley, and from the lower end of the flume, which terminates a mile east of La Mesa colony, is a pipe line 8 miles in length carrying the water to the city limits of San Diego. The cost of the Cuyamaca reservoir is estimated to have been nearly $50,000, of the flume upward of $800,000, and of the entire system $1,500,000.

There are several other projects of great magnitude and in various stages of construction or operation, some of these being under the control of companies and others of the irrigation districts. Among these should be mentioned the works of the San Jacinto Land, Flume, and Irrigation Company, the Hemet Water Company, the Fairview Land and Water Company, in the San Jacinto valley, and others elsewhere, each deserving more than casual mention. All of these large systems involve the storage of water and its distribution through pipes or tight conduits. Surveys have been made for a number of other schemes, but progress has been slow on account of the enormous expenditures involved. On the side of the mountains toward the desert, in the lower valleys, are several opportunities for the development of irrigation, some of which have already been used, as in the case of Palm valley. These localities are perhaps unrivaled for the early production of fruits.

In the northern end of the county, in the San Jacinto valley, and also on the east of the mountains, are a number of artesian wells, some of these being utilized in irrigation. Besides the flowing wells, water is obtained at various points in the county from wells pumped by wind power, a few acres near each well being thus brought under cultivation. According to the enumeration made in 1890 there were 60 flowing wells on farms, most of these being in the vicinity of San Jacinto, about 20 miles southerly from San Bernardino. These are from 108 to 389 feet in depth and have an average flow of 112 gallons per minute. Many of them decrease in discharge during the summer. In the eastern part of San Diego and San Bernardino counties, beyond the mountains, a few flowing wells have been reported, notably at Indio and in the Mohave desert, and there is probability that in many places artesian conditions prevail; also, north of this great desert area, in Owens valley, near Independence, is a small flowing well. Many attempts have been made to obtain water along the route of the Southern Pacific railroad, some of these being successful. At Indio and Walters stations, near the edge of the desert, having elevations respectively of 20 feet and 195 feet below sea level, good water has been found at depths of from 75 to 100 feet below the surface. From Walters to Yuma, a distance of 107 miles, no water suitable for locomotives has been obtained. At the station called Flowing Well a hole was drilled to the depth of about 400 feet and an artesian flow of brine was obtained.

There are 8 irrigation districts within the county, known respectively as the Elsinore, Escondido, Fallbrook, Linda Vista, Murietta, Perris, Jamacha, and San Jacinto and Pleasant Valley. The Elsinore district, including the towns of Elsinore and Wildomar, has accomplished little, and it is probable that the district organization has been definitely abandoned. The Escondido district made surveys to determine the feasibility of obtaining water from San Luis Rey river and from storage sites among the mountains. It is reported that attempts have been made to dissolve the district organization. The Fallbrook district includes 12,000 acres between Santa Margarita and San Luis Rey rivers. The assessed valuation is $426,545, and bonds to the amount of $400,000 have been voted. Difficulty has been experienced in selling these, and it is stated that assessments have been levied for current expenses. The Linda Vista district consists of 42,000 acres north of San Diego river. The assessed valuation of this is only $515,340, but bonds to the amount of $1,000,000 have been voted. Various surveys have been made in order to determine the most available source of water supply.

The Perris district adjoins the Alessandro district, as mentioned in the description of San Bernandino county. The area of this is 13,422 acres, the assessed valuation $624,054, and bonds have been voted to the amount of

$442,000. Of these $240,000 have been exchanged for water supply and $74,500 sold for cash. Water is obtained from the Bear Valley Company, being conducted to the district by means of a wooden pipe, shown in the illustration. Considerable dissatisfaction has been expressed concerning the original propositions for supplying water and the lines of the district have been changed, excluding owners who objected to certain arrangements. The Jamacha district is east of San Diego and north of Sweetwater river, including 22,000 acres of land adapted for fruit culture. The assessed valuation is $830,000. Bonds to the amount of $700,000 have been voted, of these $165,000 being traded for water. The San Jacinto and Pleasant Valley district, including 18,000 acres in the vicinity of Winchester, proposes to obtain water from San Jacinto river, having purchased certain rights from the Florida Water Company.

SAN FRANCISCO COUNTY is the smallest in the state, and comprises the point of the peninsula upon which the city of San Francisco is located. Agriculture can hardly be said to be carried on within the county, but the enumerators have found a number of areas under cultivation. These are principally devoted to truck farming, and for the most part are watered by means of windmills or other devices for pumping from wells. Most of the irrigated areas are owned or operated by Italians and Chinese, who give constant care and attention to the cultivation of the ground, raising crop after crop in as rapid succession as the conditions will permit.

SAN JOAQUIN COUNTY is south of Sacramento county, occupying the lower end of the San Joaquin valley, partially including the delta at the junction of the Sacramento and San Joaquin rivers. A number of large streams coming from Tuolumne, Calaveras, and Amador counties on the east cross this valley land on their way to join the large rivers above mentioned. Taking these in order from the south, the first is Stanislaus river, forming the southern boundary of the county. About 20 miles north of this is Calaveras river, and beyond this Mokelumne, this latter stream near its mouth forming the dividing line between this and Sacramento county. The broad plains between the rivers are devoted mainly to the cultivation of cereals, for the successful production of which there is usually ample rainfall. The lower overflowed lands on the west have to a large extent been reclaimed by levees, the farms thus made having great value. Horticulture has been of comparatively small importance, but the area in orchards is being extended as the demand for fruit increases.

The water supply of the county is large, for besides the rivers above mentioned there are a number of streams whose waters flow out from the foothills during the spring and early summer. Except in the higher parts of the county wells can be had at moderate depth, and from these a practically inexhaustible quantity of water is obtained. Many windmills are in use, pumping from these wells and irrigating gardens and fruit trees, especially in the vicinity of the towns. Comparatively little water is used for this purpose, since by careful cultivation trees and vines flourish at most localities. In the vicinity of Lathrop and Stockton are a number of artesian wells, none, however, being reported upon farms in the census year. There are also several deep wells yielding inflammable gas, the supply of which is reported to be large and of considerable value for lighting and heating purposes.

The Stanislaus river, on the southern edge of the county, has been measured, as shown further on in the description of Stanislaus county, and gaugings have also been made of the Calaveras and Mokelumne. The observations on the Calaveras river, given below, were made at a point several miles above Bellota, being thus near the county line. It is stated that the drainage basin of this stream, not extending back to the higher mountains, does not furnish as constant a flow as does that of the Mokelumne. The following table gives the results as computed by the California state engineering department:

DISCHARGE IN SECOND-FEET OF CALAVERAS RIVER AT BELLOTA, CALIFORNIA.

(Drainage area, 491 square miles.)

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1879	229	648	1,068	680	166	98	24	....	....	....	....	295	267
1880	221	393	614	4,174	1,473	196	24	10	....	....	....	246	613
1881	1,473	2,700	982	982	196	74	49	....	....	....	....	74	544
1882	344	442	1,719	1,719	2,946	246	....	....	....	98	147	147	651
1883	491	393	737	982	491	196	....	....	....	74	24	49	286
1884	196	2,455	2,946	2,455	491	491	196	....	....	....	....	....	....

The Mokelumne river was measured by the California engineers at a point north of Clements and observations of water height made at a bridge about 12 miles above. From the data thus obtained the estimate contained in the table on the following page was prepared.

DISCHARGE IN SECOND-FEET OF MOKELUMNE RIVER AT LONE STAR MILL, CALIFORNIA.

(Drainage area, 657 square miles.)

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1879	328	1,198	1,369	3,065	3,247	2,629	538	164	26	19	59	465	1,176
1880	279	396	644	4,553	5,031	6,054	2,745	365	29	164	98	291	1,721
1881	1,037	3,049	1,128	3,195	3,034	1,237	159	98	98	66	207	624	1,160
1882	591	624	1,971	2,628	4,927	3,285	788	66	59	230	207	207	1,299
1883	414	328	591	1,971	3,942	2,628	657	263	98	98	132	132	938
1884	164	1,971	3,942	3,942	3,285	2,957	2,628	657	131	98	....	....	....

A number of projects for irrigation works have been undertaken at points within this county, and considerable sums of money have been subscribed or invested, but up to the time of the taking of the census a comparatively small amount of land had been brought under ditch. One company has been formed for the purpose of irrigating land near Lodi by means of water from Mokelumne river, this being diverted by means of a dam 280 feet long and 30 feet or more in height. From the dam a canal has been projected 30 feet wide on bottom and having a capacity of nearly 600 second-feet. This will conduct water to the channel of Bear creek, which is to become a portion of the distributing system. Other companies have begun work with the intention of diverting water from the Stanislaus river, and it is probable that the area cultivated by the artificial application of water will be greatly extended, especially upon the higher lands on the eastern border.

San Luis Obispo county includes the area between Kern county and the Pacific ocean. It thus consists of a portion of the hilly and mountainous country designated as the coast range, together with the intermediate valley lands. Stock raising and dairy farming are the principal industries, horticulture occupying a relatively small area. Irrigation is not practiced, although the water supply of the county is large, and in the interior valley especially water could probably be applied to advantage during the summer months. Within the county there are reported to be a number of flowing wells, these being on the low lands near the mouth of Santa Maria river, and at localities where it is not necessary to irrigate.

San Mateo county includes the peninsula south of San Francisco and extends along the coast southerly, the total length being about 40 miles. The greater part of the surface is hilly or even mountainous, the highlands sheltering the areas along the bay of San Francisco and shutting off from the eastern side of the county the fog and damp sea breeze. Agriculture is carried on to a small extent, mainly in connection with the large estates and country homes of citizens of San Francisco. No irrigation is reported, since the precipitation is ample for the needs of the crops and fruit trees.

Santa Barbara county has a moist climate, and irrigation is confined mainly to watering orchards, vineyards, and gardens in the vicinity of the towns along the southern coast, especially during the latter part of summer. The water supply is small, being derived from the streams flowing from the mountains bordering the coast. The greater part of the land is irrigated by means of pumps or engines or by pipe lines laid from some spring or mountain stream. North of the Santa Inez mountains, which stretch along the southern coast, are several broad valleys in which agriculture is carried on successfully. It is probable that irrigation may be introduced to a small extent as development proceeds, as there are a number of streams whose waters can be utilized at reasonable expense.

Santa Clara county is immediately south of the lower end of San Francisco bay and includes the valley of which the bay may be considered as a continuation. The lower lands in the center of the county are protected from the ocean winds and fogs by the mountain range on the west, and the water supply is increased by a nearly parallel range on the east. Throughout the broad Santa Clara valley and among the adjoining foothills the cultivation of fruit is carried on extensively, and the area thus under cultivation is increasing with great rapidity. Among the fruits prunes are probably the most important, and next to these come peaches, apricots, and then the vineyards, from which are obtained both raisin and table grapes. Much of the fruit is shipped to market in the undried or what is known as green condition, but larger quantities are canned, dried, or otherwise preserved for sale and use throughout the year. Irrigation is practiced to a relatively small extent. Most of the orchardists claim that the nonirrigated fruits are better in flavor than those irrigated, although as a matter of course much depends upon the skill in cultivation and in applying the water. Orchards and vineyards in which the trees and vines have been properly placed and the soil thoroughly cultivated yield as a rule large returns. The soils of the county vary and there are undoubtedly localities in which, owing to the dry, sandy condition of the soil, irrigation is absolutely necessary.

The Santa Clara valley is noted for the large number of flowing wells. In 1890 there were 460 of these enumerated as being upon farms, the depth ranging from 59 to 740 feet and averaging 280 feet. The average cost was $555 per well, and the average discharge of those then flowing was 316 gallons per minute. The earliest of these were sunk probably about 1855, and at that time all had a strong perennial flow. As the number has increased, however, the discharge in most cases has diminished, so that now many of the wells only flow during the rainy season, and in nearly if not quite all the discharge is less during the summer than during the winter. The flowing wells are mainly on the low lands near the bay, and in many cases the pressure is very slight, only sufficient to raise the water a few inches above the level of the ground. In a few instances, however, water has been reported as rising as high as 20 feet above the surface.

Most of the artesian wells have been allowed to flow continuously in order to furnish water for stock and other purposes, and apparently the local regulations requiring that wells be capped or otherwise closed when the water is not in actual use have not generally been obeyed. Thus a large proportion of the water has been allowed to run to waste, decreasing the pressure and injuring the whole basin. In some instances where the wells do not flow, steam and wind power are used to bring the water to the surface. Outside of the known artesian area a number of attempts have been made to find flowing water, and in one case a well was drilled to the depth of 950 feet, but without success. The water is generally warm, sometimes warmer than the atmosphere, and is used mainly for watering stock, for which purpose most of the wells were sunk. In many instances, however, strawberries and vegetables are irrigated, as well as a small acreage of forage. The small amount available from any one well requires great care and economy in its use. It has been the custom to measure the quantity in the wells roughly by means of the vertical height to which the water column rises above the open end of the pipe. A remarkably large well, one having unusual pressure, would be characterized by the spouting of the water to a height of from 10 to 12 inches above the top of the pipe, this being the elevation of the upper surface of the water.

Besides the flowing wells northerly from San Jose there are a number toward the southern part of the county near Gilroy and at points along the lower part of the valley. Also on each side of San Francisco bay northerly from the county are other flowing wells, as, for instance, in San Mateo county near Menlo Park, Redwood, and other towns. In San Francisco county also are a number of deep wells, but these, so far as reported, are pumped by means of windmills. In most of the wells on the west side of and near the bay, water rises about to the level of the surface, and is raised for watering gardens, strawberries, vines, and bushes, and for lawns and domestic purposes by means of the ordinary windmills. On the east side of the bay north from Santa Clara county are also flowing wells, 34 of these being reported in Alameda county. These in general behavior are similar to those above described.

SANTA CRUZ COUNTY includes a relatively small area of land lying along the ocean west of Santa Clara county. The greater part of the surface is mountainous, and the precipitation is sufficiently heavy to insure the success of farming operations upon the bodies of agricultural land. On the lower grounds near the coast a little irrigation is practiced, as in adjoining counties, water being applied during late summer to the gardens and trees. For this purpose there are a few small ditches, and in a number of instances water is pumped from wells or other sources of supply. In the vicinity of Watsonville there are a number of flowing wells, mainly on the low ground within a mile of the coast. In all, 33 were enumerated as being upon farms in the census year. Some of these wells, which formerly discharged all the year round, now flow only at high tide or after the winter rains. The water from these wells is used to a very small extent for irrigation.

SHASTA COUNTY is at the head of the Sacramento valley, including in its southern end a relatively small portion of the valley, together with the mountains which surround it on three sides. There are a number of large streams flowing through the county, but most of them are in deep, narrow valleys, rendering the diversion of their waters upon the farming lands of the county expensive if not impossible. Irrigation is not necessary for the production of the cereals and other field crops, since the precipitation during the winter is heavy and most of these products are nearly ready for harvesting by the time the summer drought begins to be severely felt. In the case of vegetables, fruit trees, and vines, irrigation, although not always absolutely necessary, is of very great benefit and is practiced whenever possible. For the forage crops, also, artificial watering increases the number of cuttings and the production per acre.

There have been a number of ditches constructed, primarily for mining purposes, as was the case in adjoining counties. The owners of some of these ditches are selling water to irrigators at the rate of 9, 10, or 12 cents per miner's inch, while other ditches have been extended and used almost entirely for irrigation. Much of the land best adapted to the cultivation of fruit is upon the benches or low hills around the sides of the valley and above the reach of water from the larger streams. Surveys have been made to determine the feasibility of bringing water from Pitt river, which flows westerly across the northern part of the county, by means of a canal through James pass, thus covering the higher fruit lands of this end of the Sacramento valley. It has been found, however, that this pass is too high to be crossed or to be pierced by a tunnel of moderate length.

In 1889 the reconnaissance and survey mentioned above and in the description of Modoc county was begun in the vicinity of Cow creek. This stream was measured on August 12, 1889, its discharge above its junction with Little Cow creek being 13 second-feet. This latter stream was discharging at that time only 0.3 second-foot. At that time there was on foot a project for taking water on the south side of Cow creek, near Millville, carrying it along for 2 or 3 miles, then across the stream by means of a pipe or flume, and southerly 5 or 6 miles to Sacramento river. Stillwater creek in the latter part of August, 1889, was carrying at points about 5 miles east of Reading about 0.4 second-foot, this being an unusually small amount. Clear creek, as measured near its mouth, was discharging from 8 to 10 second-feet. Castle creek, in the northern part of the county, was ascertained to have a low water discharge of approximately 30 second-feet. The above figures, so far as can be ascertained, comprise the stream measurements made within this area, and although fragmentary they serve to give some idea as to the size of the smaller streams.

Fall River valley can probably be brought under irrigation almost entirely by means of canals heading near Pittville and deriving their supply from Pitt river. In the continuation of the survey mentioned in the description of Modoc county it was found that a canal heading in the canyon above Fall River valley would command about 30 square miles of territory. In this part of the county there are a few flowing wells similar to those across the line in Lassen county.

SIERRA COUNTY occupies a narrow strip between Nevada and Plumas counties and consists mainly of steep mountains and narrow valleys. On the northern side, and partly in Plumas county, is the broad Sierra valley, lying at an altitude of a little under 5,000 feet. This, as mentioned in the description of Plumas county, is drained to the northwest by the middle fork of Feather river. A number of streams enter this valley from the mountains upon all sides, most of these sinking in the pervious gravels near the edge of the plain. In spring the flood waters are conducted out upon the nearly level lands, irrigating large areas of hay and relatively smaller patches of cereals. Much of the grain, however, is sown in the fall and reaches maturity before it can be injured by the long summer drought. The irrigating ditches are small, seldom exceeding a mile in length. As previously mentioned, there are a number of flowing wells in the Sierra valley, these ranging from 45 to 1,130 feet in depth, the average being 458 feet. The quantity of water delivered is small, averaging only 47 gallons per minute. The water is allowed to flow out upon the ground, irrigating the grass lands adjacent to the well. Southwesterly from the Sierra valley are a number of mining ditches, some water from which is sold to fruit growers at the rate of about 12.5 cents per miner's inch for 24 hours.

SISKIYOU COUNTY is the central of the three counties in the northern end of California adjoining Oregon. It includes on the west a portion of the heavily timbered area of the coast mountains, and from these extends easterly to the lava covered plateau of the Great Interior basin. The Klamath river crosses the northwesterly part of the county, flowing in a narrow, deep valley, and receiving numerous large tributaries from the south. In the southeastern portion of the county is Mount Shasta, from which flow creeks belonging to the drainage system of Sacramento river. West and north of Shasta are several large valleys in which agriculture has come to be of importance, although still secondary to mining and stock raising. In these valleys, Scott, Shasta, Little Shasta, and Butte, cereals are raised without irrigation, although greater success is attained by the artificial application of water. The irrigated areas are devoted mainly to the raising of forage crops and to a less extent to orchards. Among the fruits raised the apples from Siskiyou county are perhaps the best known.

The development of mining has been of advantage to agriculture in its earlier stages of development, not only by furnishing home markets, but also by providing in many instances means of water supply. Some of the old ditches built for hydraulic mining have been utilized in irrigation, while in the case of others more or less water has been sold at certain seasons of the year. As a rule, however, irrigation is carried on by means of small ditches built by the farmers, each mountain stream being utilized, especially those flowing into the valleys previously named. Along Klamath river water is raised by bucket wheels, but owing to the difficulties no large canal for irrigation purposes has been built. As in adjoining counties, most of the irrigated areas are large and consist of lands flooded by the simplest and cheapest methods possible. Taking the county as a whole, it may be said that in the western end irrigation is not essential, since the small grains can be raised by careful cultivation, good crops of wheat being obtained by summer fallowing. The farther east one goes, however, the greater the necessity of irrigation and the more eager is the demand for water conservation and systematic control. Attempts have been made to find flowing water, and there is reported to be a well 700 feet deep in the vicinity of Yreka.

There are no large irrigation canals in the county, and the number of small ditches is so great that an enumeration of them has not been undertaken. A few of the typical irrigation works may be described briefly. The Farmers ditch takes water out on the east side of Scott river 2.5 miles below Callahan. The total length is about 10 miles, the width 4 feet, and the cost was approximately $3,000. It covers over 1,000 acres in Scott valley. Water is taken out for use about 2 miles below the diverting dam, which is built of tree trunks, brush, and stone. The water is divided by means of flumes 12 feet in length, in which a certain portion of the water is taken out. For example, if a farmer owns one-eighth of the ditch a division board is placed one-eighth the width of the flume and the water entering this narrow part is let out at the side. The principal crop irrigated is alfalfa, next in importance being the gardens and fruit trees. During April, May, and June the discharge of Scott river is so great that relatively but a small portion is utilized, but after July, especially in dry years, all of the water is diverted by the different ditches.

SOLANO COUNTY is in the lowest part of the Sacramento valley about midway between San Francisco and the city of Sacramento. It is bordered on the south by Suisun bay and connected bodies of water; the southern portion of the county as well as the eastern consists largely of swamp or overflowed lands, some of which have been reclaimed and form one of the richest farming sections of the state. There is ample moisture for all crops not only on these low lands but also among the hills and valley lands in other parts of the county, the annual rainfall being relatively large. Irrigation is not practiced, but the attempt is made rather to take away the surplus water. In the Vaca valley, lying in the northwestern part of the county, large quantities of fruit are produced, this locality being noted for the early ripening of its products. There is a good water supply and irrigation could be carried on if deemed essential, but most of the fruit growers state that the fruit is finer without the artificial application of water.

SONOMA COUNTY is on the northern coast, lying north of Marin, and including the greater part of the drainage basin of Russian river. It is noted for its vineyards and perhaps to a less extent for its fine orchards. For fruit culture and general farming the rains furnish sufficient moisture, although in the latter part of summer water might often be applied advantageously. Although irrigation in the larger sense of the word is not practiced, yet, especially in the vicinity of each large town, there are numbers of small market gardens owned by Italians, who employ water freely throughout the dry season. By this means they are enabled to raise vegetables and cause them to ripen at almost any time of the year, crop following crop in rapid succession. One or two farmers state that they have irrigated small patches of alfalfa, although this plant does well in most localities by dependence upon rainfall, especially on the bottom lands. It is necessary to cultivate the lighter soils thoroughly, for as a rule little rain falls from May 10 until harvest time. There are no flowing wells reported in the county, but there are a number of drilled wells, of from 20 to 60 feet in depth, from which water for gardens is pumped by windmills.

STANISLAUS COUNTY extends across the San Joaquin valley north of Merced county, to which it is similar in many respects. On the east side of the valley are irrigation canals from Merced river, Tuolumne river, and other streams, and on the west side the extension of the San Joaquin and Kings River canal. The areas irrigated in the census year were planted mainly to alfalfa and forage crops, fruit at that time having relatively little importance.

The principal irrigating canals in operation are the San Joaquin and Kings River canal, just mentioned, on the west side of the county, the San Joaquin ditch, on the east side, and the Knights Ferry Water Company's ditch. A small supply of water is also obtained from flowing wells, a number of which are reported in the vicinity of Hills Ferry and Crow Landing. Lands under irrigation are stated to be worth from $60 to $150 and upward, while the wheat lands above the ditches are quoted at from $20 to $30 per acre.

The principal rivers of this area are the San Joaquin, flowing northwesterly through the county, and its tributaries, the Stanislaus and Tuolumne, both of these coming from the Sierra Nevadas to the northeast. The Stanislaus for a portion of its course forms the northern boundary of the county, while the Tuolumne flows into about the center of this area. Measurements of the amount of water in these streams were made by the state engineering department, and the discharges computed from November, 1878, to October, 1884. The gaugings on the Tuolumne were made near the railroad bridge south of Modesto, the record of heights being kept from 1879 to 1882, with occasional observations at a later date. The computations of discharge were based on the data thus obtained.

DISCHARGE IN SECOND-FEET OF TUOLUMNE RIVER AT MODESTO, CALIFORNIA.

(Drainage area, 1,635 square miles.)

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1879	478	1,876	2,797	4,456	5,086	7,061	1,977	183	39	30	101	903	2,083
1880	400	625	832	7,141	10,371	14,075	7,618	1,233	134	56	35	1,065	3,635
1881	2,884	6,755	2,879	6,260	7,274	5,225	1,996	391	125	130	193	690	2,894
1882	620	573	2,164	3,543	7,461	8.048	2,745	574	225	873	570	327	2,310
1883	654	490	1,310	3,270	8,180	6,540	1,635	490	327	262	327	327	1,984
1884	410	490	6,540	7,360	7,360	8,180	6,540	1,635	327	245	....	....	....

Measurements of the discharge of Toulumne river near Modesto were attempted in December, 1889, by Mr. William P. Trowbridge, jr. At that time the rainfall was exceedingly heavy, producing unusually high floods. The results of this work show that the river was about 220 feet wide, had a maximum depth of 18 feet, and discharged nearly 20,000 second-feet in flood. On January 4, 1890, with a gauge height of 11.4 feet, the river discharged 5,873 second-feet, and on January 17, 1890, at a gauge height of 8.7 feet, it discharged 4,053 second-feet.

The Stanislaus was gauged at Oakdale and from a relatively few observations computations of the monthly mean discharge were made, the estimates being based upon the probable run-off, the character of the drainage basin being known. The results thus obtained are shown in the table on the following page.

DISCHARGE IN SECOND-FEET OF STANISLAUS RIVER AT OAKDALE, CALIFORNIA.

(Drainage area, 1,051 square miles.)

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1879	525	1,994	4,523	4,307	4,098	4,387	1,584	126	21	21	74	630	1,858
1880	315	526	630	5,781	7,251	7,742	3,255	735	74	32	21	630	2,249
1881	2,102	5,255	2,102	4,729	5,255	2,733	960	380	140	120	150	1,488	2,116
1882	398	908	4,771	3,782	5,155	5,255	1,892	105	105	473	368	210	1,869
1883	525	420	840	2,102	5,255	4,204	1,051	315	210	168	210	210	1,293
1884	263	3,153	4,204	4,729	4,729	5,255	4,204	1,051	210	158	....	....	....

There are in this county two irrigation districts, the Modesto and Turlock, each having its own system of canals, but uniting in the construction of the dam across Tuolumne river. This is being built near La Grange at a point about one-fourth of a mile below the boundary of Tuolumne county. This dam is curved in form and built of rubble masonry and concrete. When completed it will be 320 feet long at crest, over 100 feet high, 90 feet thick at base and 20 feet at top. It may be called upon to stand an overflow of more than 100,000 second-feet. The cost will probably be upward of $500,000. The Modesto district was formed in 1887, bonds to the amount of $800,000 being voted in December of that year. The district comprises 80,564 acres along the Tuolumne river in the vicinity of Modesto. The main canal furnishing water for this is computed to carry 640 second-feet. After following for about 2 miles along the steep bluffs of the river it enters upon the plateaus and benches, over which the construction is relatively simple with the exception of the crossings of deep ravines.

The Turlock district was formed in the spring of 1887, including 176,210 acres, a portion of this being in Merced county. For the construction of the dam and canal bonds to the amount of $1,200,000 have been voted. The canal is computed to have a capacity of 1,500 second-feet. The upper section of this canal was very expensive, since it was cut into slate, cemented gravel, and other rocks, and has 3 tunnels. Beyond the rock work much of the earth cutting was done by hydraulic works, water being obtained from the Hydraulic Mining Company's reservoir by means of ditches and flumes constructed for the purpose. At the end of the main canal are 5 laterals distributing water over the district. Over $800,000 has been expended in construction and buying rights of way.

Sutter county includes a portion of the low lands of the Sacramento valley lying mainly between the Sacramento and Feather rivers. The county may thus be said to consist of a vast plain only a few feet above the average level of the rivers, this plain being broken only by the Marysville buttes, which rise to altitudes of from 1,800 to 2,100 feet. In the southern part of the county much of the land is annually overflowed, while other portions are protected from inundations by an elaborate and expensive system of levees. Irrigation is not practiced, since the soil in nearly all portions of the county is more or less saturated with water, remaining fairly moist through the droughts of summer. The only instances in which water is applied to the crops are perhaps in the case of the Chinese gardeners, who raise water from wells or from the river by means of windmills or what are known as China pumps. There is probably no portion of the county so dry but that good crops can be produced by cultivation. Southwesterly from Marysville about 16 miles is a well 360 feet deep; also at Marysville, in Yuba county, is a second well 306 feet in depth, neither of these wells flowing. Northwesterly from these, at Norman, in Colusa county, a well 1,000 feet in depth is reported as discharging a small quantity of water, none of this, however, being of use in irrigation.

Tehama county lies across the northern end of the Sacramento valley south of Shasta county. Sacramento river flows southerly across this area, receiving from the east a number of streams which rise in the vicinity of and south of Lassen peak. On the west side the streams are of less importance, most of them entering the edge of the valley only, except during the time of melting snow. On the valley lands cereals are raised without irrigation, and many of the farmers state that it is not necessary to apply water even to fruit trees and vines. Irrigation, where practiced, depends mainly upon water from the east side streams, Battle, Antelope, Mill, and Deer creeks, the latter being especially notable for the number of ditches taken from it. The production of fruit and grapes is rapidly becoming the leading industry. Many of the vineyards are seldom irrigated after the first year, but it is claimed that better results can be obtained by a judicious use of water. In the southern end of the county there has been formed an irrigation district known as the Kraft district, comprising 13,500 acres, the greater part of this being in Colusa county.

Trinity county lies west of Shasta and Tehama counties, separating these from Humboldt, which borders on the ocean. It thus lies wholly within the coast range, the surface being mountainous and heavily timbered. Mining is the principal industry, and after this in importance comes stock raising. The agricultural areas are mostly small and scattered through the valleys, of which there are only two of notable size, Hay Fork and Trinity. Irrigation, though not strictly essential, is practiced for the purpose of increasing the hay crop and insuring the success of fruits, trees, and gardens. There are in the county a large number of ditches built for mining, some of which are now used in whole or in part for irrigation purposes. These take water mainly from the mountain streams rather than from the large rivers like the Trinity. The water supply of the county as a whole is ample, although there are a few complaints from farmers that the miners interfere with their obtaining water necessary for the full development of the arable lands.

TULARE COUNTY extends from the summits of the Sierra Nevadas westward across a portion of the San Joaquin valley, narrowing in this direction so that its western boundary on the coast range is very short. It includes in this western apex Tulare lake and a large part of the moist grounds or marshes surrounding that body of water. In the eastern end of the county among the high Sierras is the Sequoia national park, and on the extreme rim is Mount Whitney, the culminating point of the range. This mountain and other peaks are drained by the head waters of King river and Kaweah river, these flowing westerly, and by Kern river, which flows toward the south. Besides these streams are many smaller creeks draining the western slopes. All of the streams flow through narrow mountain valleys, in which a little irrigation is practiced, mainly for winter feed for the cattle, which find an excellent summer range among the mountains.

Nearly all of the agricultural operations of the county, however, are upon the lower lands in the broad San Joaquin valley east of Tulare lake. Here the development, as in the other valley counties, has been very rapid. At first great areas of the small grains and alfalfa were irrigated, but of late years the large ranches have been cut up into smaller farms or colonies and large areas set with fruit trees and vines, resulting in a rapid increase in population and in values. Much of the land is of peculiar composition and texture, receiving water readily and transmitting it for long distances, so that it is not necessary to irrigate the land directly, at least in the manner usually practiced in other counties, the mere presence of water standing in a ditch around a 40 or 80 acre lot being sufficient. For example, in what is known as Mussel Slough or Lucern, a section of country about 24 miles in length and 12 miles in breadth lying between Kings river and the eastern shore of Tulare lake, irrigation is almost entirely by seepage. Ditches are run at a distance of from one-fourth to one-half mile apart, no water being applied directly to the surface. The main source of water supply for this region is King's river, from which 5 large canals are taken, the Peoples, Mussel Slough, Last Chance, Lower Kings, and Rhoads, these having an aggregate length of over 110 miles. Besides these are the Settlers and Lakeside ditches from Cross creek, the whole forming a complete network.

The Kaweah delta is a name sometimes given to the region east of Mussel Slough or Lucern. This area, as shown on the accompanying map, has a length of about 30 miles and a breadth of approximately 20 miles. It is intersected by the numerous branches of Kaweah river and by the many canals leading from these. On the lower lands of this area, as well as in Mussel Slough, are a number of artesian wells, and in places the land is naturally so moist that good grain crops can be raised without irrigation on lands remote from canals. On all these lands the orchards are irrigated at least once a year, when first set out the water being run along furrows on the surface. There has been some trouble from alkali on these soils, owing to careless irrigation and poor methods of cultivation.

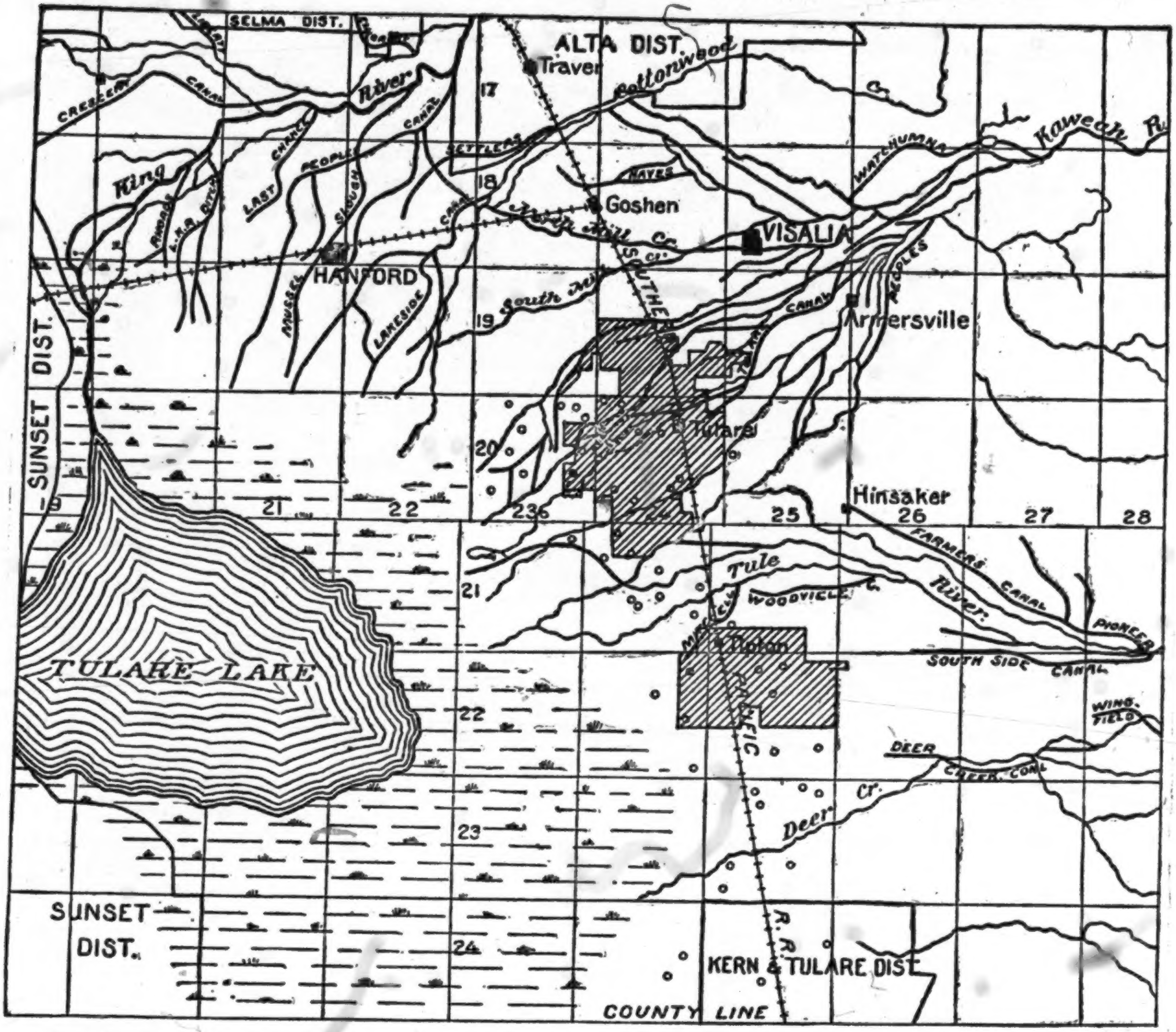
The water supply of the county comes almost entirely from the high mountains on the east, there being within this area several rivers of notable size. The largest of these is Kings river, which touches the northern boundary of the county, supplying canals both in Fresno and Tulare counties. South of this is Kaweah river, which flows in almost a straight line from Mount Whitney toward Tulare lake. South of this in turn are Tule river, Deer creek, and White creek, the line of Kern county being near the latter. The state engineering department of California carried on measurements of the discharge of these rivers and computed the maximum, minimum, and mean quantity delivered during the greater part of the period from 1879 to 1884.

Kings river, as stated in the report named above, is one of the most important irrigation feeders in the state, having a high watershed of the best character for plentiful and well delivered supply. Gaugings were made at a number of localities between Slate Point, 5 miles above Centerville, the place where it leaves the mountains, and Tulare lake, 65 miles below. These gaugings have not been in all respects satisfactory, but nevertheless are of very great value as showing the range in quantity of water discharged. At the railroad bridge south of Kingsburg, and below many of the canals, a record of the height of the river has been kept for many years, furnishing partial data for the estimation of the quantity of water available, as given in the description of Fresno county. (*a*)

---

[a] Physical Data and Statistics of California, page 409. The record of gauge height kept by the Southern Pacific company at this bridge near Kingsburg is shown in graphic form in the twelfth annual report of the United States Geological Survey, part 2, 1891, Irrigation, page 314.

MAP OF IRRIGATING CANALS IN THE VICINITY OF TULARE, TULARE COUNTY, CALIFORNIA.


SELMA DIST.
ALTA DIST.
Traver
Cottonwood
Kaweah R.
Crescent Canal
King River
Last Chance
Last Peoples
Settlers
Watchumna
Hayes
Goshen
VISALIA
Hanford
Mussel Slough
Lakeside
South Mill Cr.
Mill Cr.
Southern Pacific R.R.
Tulare
Persian
Farmersville
Sunset Dist.
Tulare Lake
Hinsaker
Farmers Canal
Tule River
Woodville
Tipton
South Side Canal
Pioneer
Wing Field
Deer Creek Canal
Deer Cr.
Sunset Dist.
Kern & Tulare Dist.
County Line
17
18
19
20
21
22
23
24
25
26
27
28

The Kaweah river drains an area wholly within this county and furnishes a water supply to lands south of those covered by Kings river. The principal gaugings were made by the state engineering department at the station near Three Rivers, and from the data thus obtained an estimate of discharge was made for the entire stream entering the valley, including tributaries which join the main stream at points below the gauging station. The following table gives the mean monthly discharge in second-feet, estimated as above stated, and the figures show graphically the character of the fluctuations during 1879 and the greater part of 1880, 1881, and 1882:

DISCHARGE IN SECOND-FEET OF KAWEAH RIVER AT WATCHUMNA HILL, CALIFORNIA.

(Drainage area, 619 square miles.)

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1879	248	279	402	867	774	557	124	31	31	62	124	279	317
1880	248	310	464	2,352	2,786	3,900	743	155	99	50	74	371	963
1881	526	774	619	1,393	1,238	990	371	155	43	74	124	279	616
1882	155	310	464	1,393	2,228	929	743	198	93	87	124	93	568
1883	155	124	619	805	1,021	990	402	99	74	62	74	74	375
1884	248	2,177	2,290	1,548	2,847	4,271	3,497	990	495	248	....	....	....

The mean discharges of Tule river, Deer creek, and White creek are shown in the following tables, these figures being obtained by computations based upon records of river height more or less fragmentary as well as upon observations and general information obtained from residents in the vicinity:

DISCHARGE IN SECOND-FEET OF TULE RIVER AT PORTERVILLE, CALIFORNIA.

(Drainage area, 437 square miles.)

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1879	57	87	61	118	105	350	35	26	26	74	140	271	104
1880	577	1,040	1,079	1,289	1,040	721	350	87	44	44	87	219	548
1881	219	437	437	874	874	437	219	175	87	66	57	66	412
1882	87	109	306	660	1,748	660	437	131	66	44	66	66	365
1883	57	87	437	656	874	874	350	87	66	44	44	66	306
1884	262	1,748	1,311	874	2,185	3,059	2,622	874	350	175	....	....	....

DISCHARGE IN SECOND-FEET OF DEER CREEK AT BASE OF FOOTHILLS, CALIFORNIA.

(Drainage area, 110 square miles.)

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1879	9	15	8	28	20	7	0	0	0	0	29	55	14
1880	132	253	286	319	220	55	6	0	0	0	22	55	112
1881	55	110	110	110	110	55	0	0	0	0	0	23	48
1882	23	17	55	55	11	0	0	0	0	11	17	6	16
1883	17	17	88	55	44	0	0	0	0	11	11	17	22
1884	55	330	330	220	44	55	0	0	0	0	....	....	....

DISCHARGE IN SECOND-FEET OF WHITE CREEK AT BASE OF FOOTHILLS, CALIFORNIA.

(Drainage area, 90 square miles.)

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1879	7	12	6	23	16	5	0	0	0	0	23	45	11
1880	108	207	234	261	180	45	5	0	0	0	18	45	92
1881	45	90	90	90	90	45	0	0	0	0	0	11	38
1882	11	14	45	45	9	0	0	0	0	9	14	5	13
1883	14	14	72	45	36	0	0	0	0	9	9	14	18
1884	45	270	270	180	36	45	0	0	0	0	....	....	....

This county, like those to the south, has a large number of artesian wells, these being located, as shown by the map, mainly within the belt east of Tulare lake and west of the main line of railroad. The total number enumerated upon farms in the census year was 139, these ranging in depth from 50 to 1,060 feet, the average depth being 587 feet. Taking the mean of all, the flow was 409 gallons per minute, this amount irrigating 100 acres per well when thus employed. Most of the wells, however, were put down for watering stock. One well, 7 inches in diameter and 1,058 feet deep, is reported as having a discharge of 1,000,000 gallons per day, or 1.55 second-feet. The water contains a small amount of sulphureted hydrogen, and some gas also issues with it. It has been used for irrigation for nearly three years, but with no injurious effects. There have been irrigated 200 acres of alfalfa and an equal amount of wheat. Taking the county as a whole, the farmers are raising a less proportional acreage of wheat and are increasing the area devoted to grapes and other fruits, and for this purpose the artesian water is especially valuable. Some of the wells, however, are unfortunately located on lands considered worthless on account of alkali.

A large number of canals have been built, taking water from each of the principal streams at points below where they enter the edge of the valley and lower down from the numerous channels or sloughs into which the rivers subdivide. The number and intricacy of these canals can best be shown by reference to the map. These canals are among the largest in the state, aggregating hundreds of miles in length. As the more important, may be mentioned the '76 canal, the Peoples canal, Mussel Slough, Last Chance, Lower Kings River, and Lakeside, deriving water mainly from Kings river, and the Watchumna, Tulare, Kaweah, from Kaweah river, the Pioneer, Farmers, and Southside, from Tule river. The Peoples ditch takes water from the south side of Kings river, the main canal having a length of nearly 7 miles and a width of from 30 to 40 feet. The total cost of the canal is estimated to have been $150,000. The canal was begun in 1873 and used in the following year. The diverting dam is made of brush, held in place by sand bags, and is repaired each year. In the construction of the canal an old slough was utilized for a portion of the distance. There are 4 distributing ditches, these being known as the Settlers ditch, taking about one-fourth of the water, the East branch taking one-half of the water, and the West branch, this again dividing and contributing water to what is known as the Middle branch. The canal is owned by a corporation, there being only about 63 shares in all. Each share is considered to be worth $1,500. The annual cost for the water is estimated to be about 50 cents per acre irrigated. The principal crops irrigated consist of grain, alfalfa, and other forage plants. Large areas of orchards and vineyards are also watered, these being of more value than the field crops. When full the ditch is supposed to carry about 500 second-feet, and, allowing for loss, each share of stock probably is entitled to about 5 second-feet of water. The full capacity is received, however, usually only during April and May. One share in this canal is thought to furnish sufficient water for from 300 to 400 acres of alfalfa and grain or 640 acres of fruit.

The Lakeside canal receives water from Kaweah river by its branches, St. John river and Cross creek. The total length of the canal is placed at 44 miles and the width 30 feet. The canal was begun in 1873 and used in May, 1875. There are two main branches, the east branch, 17 feet wide on bottom, and the west, 22 feet wide on bottom. Besides these are five others, ranging from 12 to 15 feet in width. The canal is owned by a corporation of irrigators, 30,000 shares of stock at $1 a share having been issued. One share is supposed to furnish sufficent water to irrigate an acre when the ditch is full, water being distributed at the rate of a miner's inch to two shares or a second-foot for 100 acres. The annual assessment is about 25 cents per acre. Alfalfa and fruits are irrigated, as well as grains and vegetables.

The Southside ditch takes water out on land south of Tule river and east of Tipton. The total length of the main ditch is 10 miles and the width 12 feet. The original cost was about $5,000. The canal was begun in 1875 and used in 1876. There are twenty distributing ditches, having an average width of 6 feet and a length of from one-fourth to 3 miles or more. The ditch is owned by partnership, the water being divided between two or more stockholders at a time and for a given number of hours in proportion to the stock owned by each. The first cost of water right is stated to have been $2 per acre and the annual assessment 50 cents per acre. For trees and vines under this canal one irrigation a year is usually sufficient.

There are three irrigation districts lying wholly within this county and four only partly included, three of these extending into Fresno county on the north and one into Kern county on the south. These districts are known as follows: Tulare, Tule River, and Tipton, in Tulare county; Alta, Selma, and Sunset, in Fresno and Tulare counties, and Kern and Tulare in the counties of the same name. Tulare irrigation district includes 40,520 acres, a portion of this being within the city of Tulare. The district was formed in 1889, and the proceedings for the formation of the district, the issue and sale of bonds, were confirmed by the superior court of the county a year later. The assessed valuation of the district in 1892 was a little over $2,000,000. Bonds to the amount of $500,000 have been voted, nearly all of which have been sold or exchanged for canal property.

Water for this district is obtained from St. Johns river, Kaweah river, Deep creek, and Cameron creek. The main canal from St. Johns river has a capacity of 500 second-feet and the canal from the Kaweah river the same. The district has acquired the water franchise of the Settlers ditch, one of the oldest in the county, claiming 157 second-feet; the water system of the Kaweah Canal and Irrigation Company, having a capacity of 500 second-feet, and all the canals, subsidiary ditches, and rights of way of the Rocky Ford Canal and Irrigation Company, capacity about 200 second-feet. The works are nearly completed, but may be extended from time to time. A portion of the lands included in this district have been irrigated for at least 10 years. The unirrigated lands are worth from $10 to $25 per acre and the irrigated lands from $50 to $150 or even more. It is estimated that the cost of water under the district organization when fully developed will be about $1 per acre a year, while under private management it has cost from $2 to $3 or more. This reduction in the annual cost, however, will only take place when all of the area is brought under cultivation.

Tule River irrigation district comprises 20,000 acres, the assessed valuation of which is $280,000. Bonds amounting to $90,000 have been voted, but so far as can be ascertained none of these have been disposed of. The Tipton district, including 17,040 acres lying mainly to the south and east of the town of Tipton, has an assessed valuation of $189,595. Bonds amounting to $50,000 have been voted, but not sold. The Alta irrigation district is on Kings river, including 129,927 acres of land lying under the '76 canal. The assessed valuation of this district is $2,507,630. Soon after formation the district purchased the '76 canal and its appurtenances, bonds to the amount of $675,000 being voted for this purpose and to cover other necessary expenses. The canal was bought in July, 1890, at a cost of $410,000, and the system of distributaries has been extended to cover nearly all of the land within the district. The Selma district includes 271,000 acres of land lying opposite the Alta district on the west side of Kings river. This, like the Alta district, has been subject to attack.

The Sunset district includes 308,000 acres lying on the west side of the San Joaquin valley northwesterly from Tulare lake. The assessed valuation is $3,080,000. Bonds to the amount of $2,000,000 have been voted for the purpose of procuring funds to bring water across to this unwatered side of the valley. Comparatively little has been accomplished as yet, owing to the difficulty or impossibility of selling the bonds. The Kern and Tulare irrigation district includes 84,355 acres on the southern border of Tulare county. Bonds to the amount of $700,000 have been voted, one-half of the issue being taken by a construction company which has undertaken to build systems of water supply.

TUOLUMNE COUNTY is east of Stanislaus county and includes the mountain head waters of rivers flowing westerly to the San Joaquin plains. Near the sources of many of these streams are small lakes or valleys, formerly containing bodies of water. These are surrounded by the lofty rugged peaks of the Sierra Nevadas, upon which the precipitation in the form of rain and snow is very heavy. There are thus numerous sites at which storage works could be constructed at relatively small expense, furnishing a supply of water for use in irrigation on the lower plains during the long hot summer. Some of these localities have been surveyed or examined by the United States Geological Survey, and descriptions of them are contained in the annual reports of that bureau. In the western or lower part of the county are larger valleys containing bodies of agricultural land upon which most of the crops are produced without irrigation. It has been found, however, that fruit raising can be carried on to profit, and that with irrigation even the citrus fruits can be cultivated. The principal orchards, however, are of apple, peach, and pear trees.

The water supply of the county is large and has been utilized to a considerable extent for mining and for power, the ditches aggregating probably over 150 miles in length. The principal of these belong to the Tuolumne County Water Company, the La Grange Company, and others. The main canal of the Tuolumne County Water Company takes water from the south fork of Stanislaus river at a point about 18 miles above Columbia, covering land in the vicinity of that town, branch lines running to Jamestown, Montezuma, Sonora, and other localities. It was constructed originally for mining purposes, but is now used to a certain extent for irrigation.

VENTURA COUNTY borders upon the ocean south of Kern and west of Los Angeles county. As in the case of the latter locality, the principal towns are near the seashore or within the valleys opening toward the ocean. Irrigation is rarely necessary except for orchards and vineyards and for late summer vegetables. The principal valley is that through which Santa Clara river flows in a general westerly direction. This is upward of 10 miles in width and contains many ranches, the principal crop being barley, which is raised both for hay and grain. Besides this are other valleys, many of which possess a climate well adapted for fruit raising, as well as for general agriculture. The water supply as a whole is good, although for complete development of resources there is necessity of water storage. There are no large systems of irrigation in any way comparable to those of counties to the east, but the ditches are mostly short, rarely exceeding 5 miles in length. As examples, may be given the following: the canal of the Sespe Land and Water Company obtains water from Sespe river at a point about 3 miles northwest of the town of Fillmore, covering land on the west side of the stream. It is 5 miles in length, 7 feet wide, and the cost is stated to have been $50,000. Water is diverted by means of a temporary wing dam, replaced after floods. Water is sold with the land at the rate of 1 miner's inch to 5 acres, the annual assessment being about $1 per acre. The largest part of the area irrigated is made up of orange groves. The Bardsdale ditch takes water from the south side of Santa Clara river about 5 miles above the mouth of Sespe river. It is 3 miles long, 8 feet wide, and is stated to have cost $2,300. As in the case of the ditch just mentioned, water is sold with the land, but the annual charges are apparently regulated by cost of maintenance. The Santa Ana Water Company takes water out on the east side of Ventura river, at a point 5 miles northwest of San Buena Ventura. The main ditch is 5 miles in length, 7 feet wide, and is used in connection with the pipe line supplying the town. The annual cost of water is stated to be from 50 cents to $1.50 per acre. Near the coast are a number of small flowing wells, most of them put down for the purpose of furnishing water for cattle and for household use, some of the water, however, being employed in irrigation.

YOLO COUNTY is one of the lower counties of the Sacramento valley, the large river of that name forming its eastern boundary. Much of the land on that side of the county is low, some being covered by tules. The western side is hilly or even mountainous, but contains one valley of considerable size, Capay, traversed by Cache creek, the outlet of Clear lake, situated in Lake county. South of this valley is Putah creek, which also rises in Lake county and flows in a general course parallel to that of Cache creek through Napa county and then for a short distance forms the southern boundary of Yolo. Both these creeks, Cache and Putah, discharge during the spring time large volumes of water, but during the droughts of late summer their waters shrink and disappear before reaching Sacramento river. Throughout the county the cereals are raised without irrigation, water being used to any considerable extent only in the vicinity of Woodland and in Capay valley for fruit and alfalfa. Attempts have been made to raise alfalfa without irrigation, but these have not always been successful, not wholly from the lack of moisture, but because of the destructive effects of the gophers. By irrigating the fields and flooding them thoroughly many of the gophers are drowned in their holes, checking the ravages.

The principal ditch of the county is that of the Woodland Ditch Company, commonly known as Moore's ditch. It takes water from Cache creek about 8 miles northwesterly from Woodland and carries it out on the south side. The main ditch extends east for about 2 miles and then divides into a number of branches. The total cost of the system has probably been over $50,000. Work was begun as early as 1856, and the ditch has been enlarged and extended at intervals since then. The capacity is probably from 60 to 70 second-feet. Water is sold by the second-foot per hour, the charge being at the rate of 16⅔ cents per hour or $4 per day. It is estimated that to flood alfalfa 3 times costs about $2.50 per acre per year. About one-half the water is used on vineyards and orchards of apricots, oranges, figs, pears, and plums. The Capay ditch takes water from the south side of Cache creek near the town of Capay. It is 7 miles long, about 12 feet wide, and the cost was $20,000. It is owned by a corporation, the shareholders dividing the water among themselves. In 1889 none of the land under ditch was irrigated owing to the abundant rainfall.

YUBA COUNTY includes in its western end a portion of the Sacramento valley lying east of the Feather river. From this stream it extends in a comparatively narrow belt northeasterly to the high Sierras, embracing thus plain and foothill regions as well as the river lands. The character of the agriculture is dependent upon these topographic features. On the rich low lands broad fields of cereals were cultivated, while the rolling and hilly uplands were devoted mainly to grazing and were considered to have little value until their adaptability to fruit culture was made known. With the cessation of hydraulic mining in the mountains and the abandonment of the network of ditches and flumes built for this purpose came the opportunities for the extension of irrigation by taking advantage of the magnificent water supplies thus offered. The large returns of fruit raising also induced the construction of new ditches, utilizing the magnificent water supply of the county. All the deciduous fruits and also oranges are profitably raised, the areas planted to fruits and vines being found not only among the hills but also down upon the lower lands.

Irrigation is not considered necessary, especially on the lower lands, for the cereals and forage plants, although as a matter of course with a well regulated supply of water the crops are better and surer. For fruits and grapes on the dryer soils, on which these succeed best, irrigation is essential. Water is obtained for these areas from the numerous ditches extended from the hydraulic works. Payment for the water is generally made by quantity and time used, the charge being in different cases 9 cents, 10 cents, or 12.5 cents per miner's inch for 24 hours, the quantity being measured under a 6-inch head. Near Marysville orange and other fruit trees are irrigated by water raised from wells by means of a steam pump. The comparatively large expense for water in these cases is justified by the value of the products, which ranges from $200 to $300 per acre and upward. Under the Excelsior Water and Mining Company's canal, leading from the South Yuba river about 6 miles north of Nevada city, the charge for water is stated to be from $3 to $5 per acre.

The Browns Valley irrigation district was organized in October, 1888, comprising 44,000 acres of some of the choicest foothill land. This district extends from the Yuba river on the south north to Honcut creek, the boundary being about 11 miles east of Marysville. Bonds to the amount of $140,000 have been voted, a large part of these being sold. The district has purchased over 20 miles of distributing ditches owned by the South Feather Water and Union Mining Company and has built 18 miles of main canal, besides flumes, bridges, and pipe lines. It has also constructed a dam across the North Yuba river 25 feet high, 140 feet long, and 40 feet thick at base. This is built of crib work filled with stone, and is for the purpose of diverting water into the flumes placed 7 feet above high water mark.

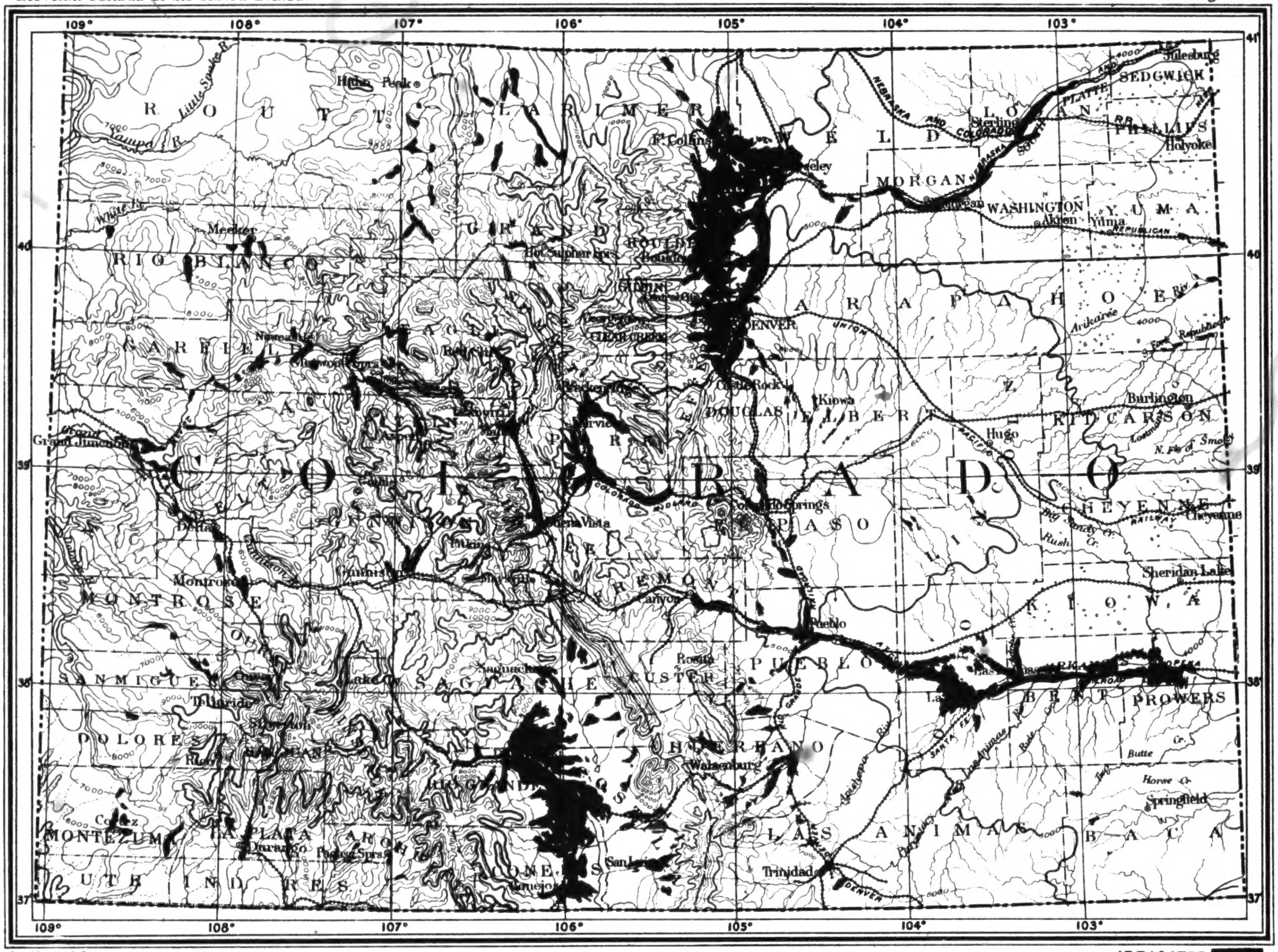
COLORADO.

Total population (average per square mile 3.98)		412,198
Number of owners of farms (3.98 per cent of population)		16,389
Number of irrigators (58.94 per cent of farm owners, 2.34 per cent of population)		9,659
Area of state, land surface (103,645 square miles)	acres..	66,332,800
Area irrigated in census year	do...	890,735
Area of all farms, 39.65 per cent improved	do...	4,598,941
Cereals raised in census year, including 117 acres in buckwheat and 4,615 acres in rye	do...	351,086
Barley, average production, 27.43 bushels per acre	do...	12,086
Corn, average production, 12.67 bushels per acre	do...	119,310
Oats, average production, 28.59 bushels per acre	do...	87,959
Wheat, average production, 22.41 bushels per acre	do...	126,999
Alfalfa	do...	126,531
Total value of all farms, including land, fences, and buildings		$85,035,180
Estimated total value of the farms irrigated in whole or in part		$59,696,000
Estimated value of all farm productions (sold, consumed, or on hand) for 1889		$13,136,810
Estimated value of productions, as above, from farms irrigated in whole or in part		$11,686,000
Average size of irrigated farms	acres..	92
Average size of irrigated farms of 160 acres and upward	do...	307
Per cent of acreage of irrigated farms of 160 acres and upward to total acreage irrigated		49.34
Average size of irrigated farms under 160 acres	acres..	55
Average first cost of water right per acre		$7.15
Average annual cost of water per acre		$0.79
Average first cost per acre of preparation for cultivation		$9.72
Average value of irrigated land, including buildings, etc., in June, 1890, per acre		$67.02
Average annual value of products per acre in 1889		$13.12

COMPARISON WITH OTHER STATES.

The above table, similar to those prepared for Arizona and California, brings together the most important data relating to the proportion of the population of Colorado interested in irrigation and concerning their farms and products. For comparison with other states and territories of the arid regions reference should be made to the general tables given in the first portion of this report. By examining these it appears that Colorado stood third in number of irrigators in 1889 and second in area irrigated. In average size of irrigated farms, 92 acres, it stood fourth, Nevada, Wyoming, and Montana preceding it. As for proportion of state irrigated, however, it stands at the head of the list, 1.34 per cent of the entire land surface of the state being watered. In total number of farms it stood second to California, while in the percentage of number of these irrigated, 58.94, it is eighth. In average value on June 1, 1890, of farm land irrigated, $67.02 per acre, the state is third, following far behind California and Utah, while in average value of products in 1889, $13.12 per acre, it was sixth, a number of these states, however, having average values of product per acre within a few cents of each other.

Classifying the irrigated holdings according to size, 160 acres being the dividing line, Colorado comes first in the number of these of 160 acres and upward and second only to California in the aggregate area, while it is fifth in the list in the proportion of these to the total area irrigated, a trifle less than one-half of the total number of acres irrigated being contained in these large holdings; that is to say, 1,432 irrigators owned nearly one-half of the irrigated lands. In average first cost of water per acre, $7.15 (ranging by counties from $2 up to $16 per acre), Colorado was fourth, following California, Utah, and Nevada. In average value of water rights per acre in 1890 it was second only to California, while in average annual cost of water per acre, 79 cents, it was among the lowest, being surpassed only by Washington and Wyoming. This average was low, from the fact that there was a predominance of cases where the irrigators owned small ditches cared for by themselves, the annual expense being from as low as 10 cents per acre up to 50 cents or more. On the other hand, there were many farmers who paid annually a stated sum to a canal company for delivering water, the prices ranging from $1.50 up to $3 per acre.


109° 108° 107° 106° 105° 104° 103°
41° 40° 39° 38° 37°
COLORADO
ROUTT
LARIMER
WELD
LOGAN
SEDGWICK
PHILLIPS
MORGAN
WASHINGTON
YUMA
RIO BLANCO
GRAND
BOULDER
GILPIN
CLEAR CREEK
ARAPAHOE
GARFIELD
EAGLE
DOUGLAS
ELBERT
KIT CARSON
PARK
EL PASO
LINCOLN
CHEYENNE
MESA
GUNNISON
CHAFFEE
FREMONT
KIOWA
MONTROSE
OURAY
SAN MIGUEL
DOLORES
SAGUACHE
CUSTER
PUEBLO
BENT
PROWERS
HUERFANO
RIO GRANDE
LA PLATA
MONTEZUMA
ARCHULETA
CONEJOS
COSTILLA
LAS ANIMAS
BACA
UTE INDIAN RES.
Hahn Peak
Little Snake R.
Yampa R.
White R.
Meeker
Ft. Collins
Greeley
Sterling
Julesburg
Holyoke
Akron
Yuma
Hot Sulphur Sprs.
Boulder
Denver
Castle Rock
Kiowa
Hugo
Burlington
Grand Junction
Glenwood Sprs.
Breckenridge
Buena Vista
Colorado Springs
Cheyenne Wells
Sheridan Lake
Gunnison
Delta
Montrose
Cañon
Pueblo
Rosita
Saguache
Telluride
Silverton
Lake City
Las Animas
Lamar
Walsenburg
Springfield
Cortez
Durango
Pagosa Sprs.
San Luis
Conejos
Trinidad
Arkansas R.
Republican
Arikaree
Big Sandy Cr.
Rush Cr.
Butte Cr.
Horse Cr.
Purgatoire R.
Apishapa R.
Platte R.
South Platte
Union Pacific
Santa Fe
Denver
7000 8000 9000 10000 4000 5000 6000

IRRIGATED ■

MAP OF COLORADO, SHOWING AREAS IRRIGATED IN 1889

The irrigated areas of the state, as shown by the accompanying map, were widely distributed, but in the main were found along the foot of the Front range, extending thus in a general northerly and southerly direction and stretching out to the eastward down the valleys of the South Platte and Arkansas. To the west of this the principal areas were in San Luis park and scattered irregularly along Grand river and its tributaries. As a rule it may be said that irrigation developed gradually and without attracting particular attention from the general public until about the close of the last decade. The earliest irrigating ditches were dug by Mexican farmers, cultivating small patches of land along the foothills, mainly in the southern part of the state. These ditches are still in use, and most of them are in their original condition, few changes or improvements having taken place either in methods of farming or in ways of distributing and applying the water. The earliest large enterprise conducted by English speaking farmers was probably the irrigation system at Greeley built by the Union colony, work being begun about 1870. As the population of the state has increased and the demand for agricultural products has become greater, farmers have gradually brought under cultivation strips or patches of arable land wherever water can be diverted to cover it at moderate expense. Thus all the easily available sources of water have been utilized, and with increase in the number of farmers still more land has been cultivated until the area far exceeds that which can be irrigated in ordinary seasons.

IRRIGATION PROGRESS.

The success of the earlier settlers in rendering valuable the hitherto desert lands stimulated speculators and owners of fertile though arid tracts to attempt to reclaim these from their worthless condition in order that they might be made sources of revenue, and from about 1887 almost innumerable projects for the construction of large irrigation works have been suggested, some being brought to completion. Many of these involved the expenditure of hundreds of thousands and even millions of dollars, the primary object being either to sell shares of stock or to realize in some manner upon the increased value of the land. In some cases stock has been sold to investors having no interest in the land, but in the majority of instances shares of stock entitling the owner to a certain proportion of the water have been disposed of to farmers having land under the canal. Sometimes the canal company has owned a large part if not all of the land, and has sought to colonize this, selling the land with water rights, generally on long time and partial payments.

The multiplication of small irrigating systems by the farmers and their enlargement from time to time continued, as previously intimated, until the demand for water, along the smaller streams at least, far exceeded the easily available supply. Added to this has been the construction of great canals, the capacity of any one or two of which, if ever brought into full operation, would exceed the amount in the principal rivers. This has brought about a condition of affairs in which in many counties the rights of the farmers to the use and employment of the waters are in a most precarious and unsatisfactory state, emphasized by the fact that the water supply of summer varies greatly in quantity from year to year. In the plan for construction of the larger irrigating canals, little if any attention has been or is now being paid to the question of water supply, and large sums have been recklessly expended, especially in eastern Colorado, in digging long lines of canals for which it seems improbable there will be sufficient water during summer.

RAINFALL AND RIVER FLOW.

The necessity of irrigation as well as the reason for the somewhat wide development of dry farming is made apparent by reference to the table on the following page, which exhibits the average distribution of precipitation in many of the counties of the state. This shows that, taking all the points of observation, the average precipitation, in the form of both rain and snow, is about 14 inches for the entire state, ranging from less than 7 inches at points on the plains up to about 30 inches among the high mountains from which come the streams used in irrigation.

MEAN MONTHLY AND ANNUAL RAINFALL AT STATIONS IN COLORADO.

LOCALITIES.	Altitude in feet.	Length of record. (Years and months.)	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Arapahoe county:															
Denver	5,281	20 10	0.63	0.54	0.92	2.07	2.61	1.34	1.60	1.40	0.96	0.78	0.81	0.66	14.32
Baca county:															
Springfield	....	a1 7	0.40	0.84	0.42	3.32	1.02	1.94	3.15	0.91	0.46	0.67	0.27	0.02	13.42
Bent county:															
Fort Lyon	4,000	a20 7	0.20	0.27	0.36	0.97	1.85	1.38	2.18	1.77	0.93	0.67	0.28	0.21	11.07
Las Animas	3,809	7 10	0.22	0.32	0.38	1.69	2.05	2.19	2.10	1.72	0.62	0.64	0.30	0.48	12.71
Boulder county:															
Longmont	5,000	a3 9	0.28	0.73	0.41	2.90	3.82	0.64	0.73	1.22	0.27	1.77	0.38	0.06	13.21
Cheyenne county:															
Kit Carson	4,280	a3 5	0.18	0.16	0.48	0.21	0.58	1.93	0.96	1.12	0.38	0.26	0.14	0.42	6.82
Clear Creek county:															
Georgetown	8,564	a4 11	0.42	0.39	0.74	1.29	1.75	0.78	2.02	1.88	0.72	0.80	0.78	0.57	12.23
Idaho Springs	7,569	a3 6	0.26	0.44	0.84	1.14	2.47	0.71	3.19	2.29	0.58	0.81	0.47	0.31	13.51
Costilla county:															
Fort Garland	7,937	a21 9	0.54	0.79	0.72	1.07	1.03	1.32	2.41	1.95	1.11	0.51	0.57	0.72	12.74
Custer county:															
Westcliffe	7,800	2 1	0.44	0.50	0.39	5.16	0.60	1.10	4.78	T	1.89	0.95	1.30	0.55	17.75
Delta county:															
Delta	4,950	2 1	0.60	0.66	0.52	0.69	0.24	0.04	0.77	1.10	0.59	1.18	1.55	1.91	9.85
Elbert county:															
Thon	5,795	2 6	0.12	0.18	0.31	1.72	2.70	0.98	1.72	2.32	0.43	0.58	0.18	0.10	11.34
El Paso county:															
Colorado Springs	6,032	a12 4	0.20	0.26	0.55	1.72	2.26	1.69	3.45	2.14	1.28	0.56	0.37	0.31	14.79
Pikes Peak	14,134	14 11	1.55	1.36	2.09	3.60	3.67	1.76	4.43	3.83	1.72	1.41	1.74	1.43	28.65
Fremont county:															
Canyon	4,700	4 1	0.87	0.75	0.44	2.56	1.10	0.34	1.21	1.80	0.34	0.90	0.76	0.45	11.52
Garfield county:															
Glenwood Springs	5,760	a2 6	1.06	1.50	1.00	0.44	1.17	0.54	0.87	2.57	0.58	1.62	2.32	2.92	16.59
Gunnison county:															
Gunnison	7,558	2 4	0.29	0.02	0.50	1.60	0.06	0.14	1.69	1.00	0.30	0.36	1.93	0.64	8.53
Huerfano county:															
Fort Massachusetts	8,365	a5 8	0.34	0.86	0.61	1.15	1.36	0.72	2.01	2.84	1.80	0.87	3.61	1.07	17.24
Jefferson county:															
Golden	5,993	a4 11	0.58	0.96	1.46	2.64	3.34	2.08	1.55	1.11	1.30	0.81	1.20	0.52	17.55
Lake county:															
Climax	11,325	a3 3	0.88	1.72	3.40	2.23	2.82	1.03	2.20	2.15	1.36	1.38	2.08	0.87	22.12
Leadville	10,200	a2 4	0.47	0.58	0.96	0.78	2.20	0.50	1.14	1.11	0.67	1.00	1.16	0.99	11.56
La Plata county:															
Fort Lewis	8,500	a10 1	1.59	1.10	1.22	1.36	0.63	0.73	2.22	2.20	1.17	1.46	1.47	2.04	17.19
Hermosa	6,700	a7 0	1.10	1.44	0.67	0.54	0.52	0.52	1.85	2.32	1.35	1.09	1.35	1.55	14.30
Larimer county:															
Fort Collins	5,000	a9 7	0.73	0.49	0.77	1.90	2.72	1.72	1.56	1.03	0.90	1.15	0.48	0.30	13.75
Las Animas county:															
Trinidad	6,070	a5 1	0.29	1.23	0.06	1.02	2.44	5.30	3.06	3.24	1.34	1.32	1.64	0.07	21.61
Mesa county:															
T. S. Ranch (*b*)	....	3 8	0.30	0.61	1.02	0.77	0.92	0.14	0.88	1.90	1.07	1.23	0.96	1.11	11.00
Montrose county:															
Montrose	5,795	5 5	0.56	0.36	0.44	1.48	0.52	0.24	0.82	1.51	0.82	0.97	0.89	0.62	9.23
Morgan county:															
Fort Morgan	4,500	a2 4	0.31	0.44	0.15	0.94	1.72	0.55	1.73	0.92	0.11	0.52	0.35	0.34	8.03
Otero county:															
Rocky Ford	4,100	2 0	0.35	0.14	0.41	2.10	0.97	0.76	2.83	1.03	0.17	1.60	0.54	0.03	10.93
Park county:															
Alma	10,320	a3 9	0.53	0.34	0.98	1.70	0.95	0.52	1.75	3.06	0.54	0.77	0.80	0.46	12.40
Como (ranch near)	9,500	5 9	0.56	0.66	1.05	2.11	1.26	0.95	3.85	2.76	0.80	0.98	1.10	0.69	16.77
Pitkin county:															
Aspen	8,000	a2 9	1.18	2.70	0.54	0.55	3.42	1.10	2.24	2.88	0.07	1.31	1.50	1.55	19.13
Prowers county:															
Lamar	....	1 9	0.14	0.40	0.34	2.74	1.40	2.06	1.88	1.23	0.46	2.39	0.40	0.04	13.48
Pueblo county:															
Fort Reynolds	4,300	4 0	0.70	0.86	1.06	4.38	1.69	0.80	1.51	1.31	1.90	0.49	2.03	0.28	17.01
Pueblo	4,753	9 9	0.25	0.29	0.40	1.86	1.76	0.68	0.90	1.89	0.36	0.73	0.06	0.09	9.87
Rio Grande county:															
Monte Vista	7,665	a4 0	0.24	0.31	0.29	1.40	0.26	0.31	1.24	0.97	0.63	0.63	0.22	0.41	6.91
Summit	11,300	a3 7	1.67	2.74	3.68	4.81	1.94	1.20	3.29	2.87	2.06	2.85	1.82	1.82	30.75
Saguache county:															
Saguache	7,740	a2 9	0.31	0.30	0.08	0.99	0.37	0.64	1.94	1.32	0.41	0.71	0.31	0.20	7.58
Sedgwick county:															
Fort Sedgwick	3,660	a3 2	0.60	1.36	0.72	2.34	1.40	0.56	1.11	1.54	1.10	0.51	0.04	0.52	11.80
Weld county:															
Greeley	4,780	a2 5	0.15	0.28	0.50	2.44	1.98	1.63	1.60	1.51	0.25	1.22	1.73	0.12	13.41

a Record broken.

b Ranch 9 miles from Whitewater, Colorado.

Although the total amount of rainfall as shown by the above table is small, yet this quantity is usually so favorably distributed throughout the year that agriculture succeeds in localities whose mean annual precipitation is less than at places to the west where the rain occurs more uniformly from month to month. In the 5 months from April to August, inclusive, or the crop season, over 60 per cent of the precipitation usually takes place. This fact is brought out more clearly by the following table, in which the average rainfall for most of the important stations of the state is given both in depth in inches and percentage of the whole amount. This is placed in comparison with the average distribution of the available water supply, that is, of the mean monthly percentage of water flowing in the principal streams. The periodical rise of the streams to their spring floods is shown in the case of Colorado to be nearly coincident with the increase in quantity of spring and summer rain, in this respect differing from California, where the streams rise about the time the rainfall diminishes. As shown by the percentages the rivers begin to increase in flow, mainly by melting snow a short time after the rainfall increases, but they decrease in July, falling off rapidly, although this is the time of greatest rainfall, and in August reach comparatively low stages, dwindling or ceasing to flow at the time when the need for water is greatest. Thus it happens that many crops which mature early in the season can be raised successfully by dependence upon the summer rains, and on the other hand, crops which are slow in maturing, or forage which can be cut a number of times in succession, require an artificial supply of water when the summer rains decrease, or may be entirely destroyed by drought when the streams no longer fill the irrigating ditches.

DISTRIBUTION OF PRECIPITATION AND AVAILABLE WATER SUPPLY.

MONTHS.	AVERAGE MONTHLY PRECIPITATION.		AVERAGE MONTHLY RIVER FLOW.
	Inches.	Per cent.	Per cent.
Total	14.00	100.00	100.00
January	0.65	4.64	3.40
February	0.60	4.28	2.90
March	0.75	5.36	3.60
April	1.45	10.36	5.60
May	1.65	11.79	20.00
June	1.25	8.93	27.50
July	2.35	16.78	13.50
August	1.90	13.57	6.70
September	1.10	7.86	4.40
October	0.80	5.71	4.40
November	0.75	5.36	3.70
December	0.75	5.36	3.30

From a careful examination of the census statistics and of replies from thousands of farmers it would appear that the great need at least for the eastern half of the state is for a more careful use of the water and for its increase by flood storage. Far larger areas could be successfully cultivated with the amount now at hand if the water were used with greater skill and economy, and, as is well known, great quantities run to waste each year in time of flood. As the matter now stands there is a deficiency of supply for the land now cultivated and reported as irrigated, and in addition there are far larger areas without water, although under ditch. The acreage of fertile land to which water can be carried by canals and ditches already constructed can not be definitely ascertained, but, especially in the eastern end of the state, it is of such extent that the patches actually watered in comparison shrink into insignificance.

RESERVOIRS.

Water storage as a relief from the trials and uncertainties of a chance supply has been eagerly taken up by irrigators and others interested in such matters, and many reservoirs have been built, some of these among the high mountains, but the greater number near the foothills in the vicinity of lands to be irrigated. The success of these has not been as marked as anticipated on account of their great first cost when properly constructed and the practical difficulties in filling them each year. With wasteful methods of employing water and the small average value of products per acre the use of water obtained by storage has not always been profitable. As the farmers become gradually more skillful in producing the best results with the least water, enterprises of this character must be more and more successful.

A few small reservoirs have failed by the washing away of dams improperly constructed or so placed as to be exposed to great floods. Other works have been so located that, although perfectly safe in every way, there has not been a sufficient amount of water each year to fill them and make up for losses by evaporation and seepage. There has been the same disregard of facts and physical data shown in the location of storage works as in the construction of large canals, more attention being given to the possible profits than to questions of water supply and stability. Examples of this kind, even though few in number, have caused more or less loss of confidence and have resulted in delays and greater care in planning and executing other structures for such purposes.

The quantity of flood water available for storage has been generally overestimated. The inhabitants of the country, seeing the angry waters rushing down valleys and tearing out bridges, dams, and other obstructions, form ideas and make statements widely at variance with the facts as ascertained by engineering examination. This is brought out most strongly perhaps by the gaugings made by the United States Geological Survey or by the state engineer. Not all of this water can be utilized, since it comes so rapidly and in such great quantities that it can not be diverted into reservoirs as ordinarily constructed. The amount varies so greatly from year to year that a system of reservoirs constructed to hold the average amount might be partly dry for several years in succession, or at other times would receive more than they could hold.

STATE SUPERVISION.

The Colorado laws regarding irrigation have grown much as has the ditch system, by adding here and there, and as a result they are far from perfect, although better than those of many of the other irrigating states. The farmers complain of the inefficiency of present methods of distributing water, of the apparent injustice that sometimes arises, and of the legal costs involved in protecting their property. In the districts where the demand for water is especially great, where old ditches have been enlarged and new canals built, continual vigilance on the part of irrigators and of state officials must be practiced in order to secure and maintain a legal distribution of water.

The theory upon which the law is based is simple, but the details for enforcing this are complicated and not always efficient. The primary object is to secure to each irrigator the use of an amount of water equivalent to that originally employed by him according to the date at which such employment was made. That is to say, the first settler on a stream should be secure in the use ever after of the amount of water originally diverted and used, and if there is a surplus the next settler should have an amount equivalent to that originally used by him, and so on. At times of drought the persons utilizing the water last in order of time should be deprived of it, and this shutting out should continue in the reverse order of the dates of appropriation until those holding what are known as prior rights have a full supply.

In order to enforce the laws regarding the distribution of water the state has been divided into six divisions, the limits of these coinciding with the watersheds of the principal rivers. Division I includes all of the drainage area of the Platte river within the state, and division II that of the Arkansas, these two covering the eastern part. Each of these is subdivided into water districts, which include one or more creeks tributary to the rivers or a portion of the main stream itself with the adjoining land irrigated. In each of these districts is a water commissioner, whose duty it is not only to know the condition of the water supply and of its employment but in time of scarcity to enforce the legal decisions as to priorities by closing the head gates of ditches not entitled to water at such times. These commissioners have police powers and must exercise considerable discretion in the execution of their duties, which require judgment and experience.

The water commissioners in each district are under the general direction and supervision of a division superintendent, and each superintendent in turn reports to the state engineer regarding the amount and distribution of water and other facts incidental to his duties. All questions, however, concerning priorities of right are adjudicated by the courts, the state engineer and his assistants carrying into effect as far as possible these judicial decisions, and unless these have been legally established the state officials can not interfere. One of the greatest sources of weakness in this system is the fact that water measurements have not been made to an extent sufficient to give comprehensive ideas of the amount available, and the decisions of the court, being based upon such evidence as was presented, relate to quantities often larger than can be realized. Decrees have been made to various ditches entitling them to two, three, or even five times as much water as could possibly be carried, the aggregate amount mentioned in the decrees being perhaps ten or twenty times as much as the river from which the water is taken carries even in times of flood.

Questions concerning priorities of right are especially perplexing in division I, where many of the adjudications were made before matters of that kind were as well understood by the public as at present. The distribution of water in some of the districts is surrounded by almost insurmountable difficulties, requiring great tact and experience on the part of the commissioners, superintendent, and state engineer in order to avoid personal conflicts or litigation. Even then in time of drought there is more or less unavoidable friction, and injunctions have been issued restraining the state engineer and his assistants from interference. Each year, however, as the irrigators come to understand the necessity and value of state interference and questions of detail are settled some of the obstacles are overcome, but at the best there are many hardships connected with the matter.

Few persons outside of the irrigating states comprehend the full significance of the statement that certain ditches have been shut down, or that the greater part of some district has been deprived of water in order to satisfy prior claims. To the irrigators under these particular ditches this deprivation may mean the almost complete loss of the results of the season's work and the jeopardizing of trees, shrubs, and other plants upon which years of care have been bestowed. Of course there are many complaints, and state officials are accused of partiality and unfairness by some of the sufferers, but the community as a whole sees in this the unavoidable operations of necessary laws. The doctrine of priority of rights has been so well established that it is not probable that it can be overthrown, although individuals often attack it bitterly.

Owing to unusual droughts and the shutting down of certain canals and ditches there were heavy losses of crops during the census year, especially under some of the larger canals. The condition of farmers thus deprived of water was deplorable, from the fact that they had mortgaged their property to pay for the water rights and paid in advance their annual rates. By being deprived of water their crops were not profitable and interest and partial payments on the mortgage could not be made. The deeds to water rights usually contain a clause practically relieving the company from responsibility in case of failure to deliver the quantity of water called for; but, on the other hand, the mortgages given by the farmer are so drawn that default of one payment makes the whole amount become due at once. Thus apparently it is in the power of a company failing to furnish water to foreclose a mortgage and obtain possession of the land.

AVERAGE COST OF DITCHES.

In Colorado there are to be found examples of nearly every type of irrigating system. The small, cheaply constructed ditches are in excess, but there are also a few well constructed canals worthy of detailed description. Without discriminating between the different conditions under which the canals have been built a general average has been taken of the cost of construction, dividing these into classes according to the width. Taking those under 5 feet in width, the average cost per mile was $380; those of 5 feet and over and under 10 feet in width cost on an average $1,131 per running mile, and those of 10 feet and over cost $5,258 per mile. This includes expenses of head works, flumes, and all other structures. Most of the older ditches have been poorly located, and a great number have been duplicated by the construction of other ditches running nearly parallel and supplying land in the same vicinity. This results in great waste of water, and the farmers as a whole have had to pay nearly double the amount necessary to have constructed one well planned ditch.

In many localities where small parallel ditches cover the ground, it has been proposed in the interest of water economy to attempt to consolidate interests and utilize the highest canal or ditch. In order to do this it will be necessary to purchase many of the older rights, the cost of which will be very large unless condemnation proceedings can be had. While the early and cheaply constructed ditches were in many ways of immediate benefit to the irrigators, enabling them to gain a foothold, yet in the long run they must prove very expensive, especially where attempts are made to improve methods of distribution and to economize water, the outlay required to do away with old methods being far greater than the construction of new.

DUTY OF WATER.

The duty of water in Colorado, that is, the area of land irrigated by a given quantity of water, varies, as in all other states, with the character of the soil, the crops, the amount at hand, the skill of the farmer, and other conditions. As a whole, it is probable that the duty has gradually increased, larger areas being now irrigated than formerly with the same amount of water. To ascertain what is the average duty is a matter of considerable difficulty on account of the varying conditions, but it is possible to arrive at this in an approximate manner by comparison of the amount of water flowing in various streams with the acreage irrigated. Taking, for example, the average discharge of Cache la Poudre, Big Thompson, St. Vrain, and Boulder creeks and comparing this with the acreage reported as irrigated in the census year, it appears that the duty of water was about 120 acres to the second-foot. This method of computation is not wholly satisfactory and yields results of little practical value. It should be noted furthermore that in this year many of the farmers claim that they did not have enough water and that a considerable proportion of the crop was a failure, or, in the case of the cereals, was cut for forage. Figures of this kind, while of use in broad discussions of the subject, can not be safely applied to any one project or used to show the probable amount of land to be irrigated from a definite source.

The best data upon the duty of water in the state are those obtained at the agricultural experiment station at Fort Collins, where careful measurements have been made of the quantities of water used upon different fields. The results obtained have been given in a preliminary report, which shows the duty of water as computed with or without the rainfall and for different periods of the irrigating season. Since the greater part of the irrigation is carried on by means of water from streams which fluctuate from day to day, reaching their flood stage in June, it is necessary to assume a certain number of days during which the discharge of the river or the canal shall be taken, the computed duty of water varying according to the time thus chosen. This report assumes for comparison four periods, viz, May 1 to September 1, 123 days; April 1 to September 1, 153 days; May 1 to November 1, 184 days, and the month of June alone, or 30 days. The corresponding duties thus obtained are shown in the table on the following page for four cases, two of these being canals, the third the whole valley watered by these and other canals, and the fourth, the same valley with an allowance made for the amount of water which probably enters the main stream by seepage below the point of measurement. Summing up the whole matter, it would seem probable that the average duty of water per second-foot, as measured at the head of the canals and flowing constantly, is from 60 to 65 acres in June, or from 175 to 300 acres for the whole season, this last representing the conditions when a reservoir is available in which the water may be stored. (a)

(a) Colorado State Agricultural College, agricultural experiment station, Bulletin No. 22, preliminary report on the duty of water, page 30.

CONDITIONS FOR IRRIGATION NEAR FORT COLLINS, COLORADO.

CANALS AND FIELDS.	May 1 to September 1 (123 days).		April 1 to September 1 (153 days).		May 1 to November 1 (184 days).		June (30 days).	
	From irrigation.	From irrigation and rain.	From irrigation.	From irrigation and rain.	From irrigation.	From irrigation and rain.	From irrigation.	From irrigation and rain.
DEPTH OF WATER IN FEET.								
No. 2 canal	2.09	2.86	2.09	3.03	2.09	2.96	0.92	1.12
Larimer and Weld canal	1.49	2.26	1.49	2.43	1.49	2.36	0.73	0.93
Valley	1.25	2.02	1.30	2.24	1.33	2.22	0.64	0.84
Valley, seepage included	1.41	2.18	1.50	2.44	1.57	2.46	0.68	0.88
CORRESPONDING DUTY PER SECOND-FOOT IN ACRES.								
No. 2 canal	112	81	146	101	176	124	65	53
Larimer and Weld canal	165	109	205	128	246	155	81	64
Valley	195	122	233	136	274	168	94	71
Valley, seepage included	174	113	204	125	244	151	88	68

YIELD OF IRRIGATED CEREALS.

It has generally been assumed that upon irrigated lands the yields per acre are heavier than on the lands farmed by dependence upon rainfall, but owing probably to the fact that most irrigators did not have sufficient water for all their fields the average yield per acre of the irrigated lands, as shown by the census, did not reach extraordinary quantities. The most that can be said is that irrigation has enabled crops to be produced where otherwise it would have been impossible to produce them, and that with ample water and the exercise of unusual care and skill notable success can sometimes be attained.

Taking the cereals in the order of their importance as regards acreage in Colorado, wheat comes first. For the whole state the average production during the census year was 22.41 bushels per acre, while in Kansas the average was 19.21 bushels per acre, in Iowa 14.09, in Illinois 16.68, in Indiana 14.52, in Massachusetts 16.19, and in Georgia 5.58. Next in importance in Colorado is Indian corn, a great part of this, however, not being irrigated. The average production for the state was 12.67 bushels per acre, while in Kansas the production was 35.49 bushels per acre, in Iowa 41.28, in Illinois 36.84, and in Georgia 11.33. Oats come next in acreage, the average production of these in Colorado being 28.59 bushels per acre, in Kansas 30.49, in Iowa 39.09, and in Illinois 35.56. Of barley the average production in Colorado was 27.43 bushels per acre, in Kansas 23.01, in Iowa 25.84, and in Illinois 28.93.

These cereal averages are not as favorable to Colorado as has been generally assumed, for there has been very great exaggeration both as to the benefits and as to the extent of irrigation. Many of the cereals in the state have not been irrigated, or if water has been applied there has not been sufficient to produce the best results. With plenty of water and a thorough, intelligent cultivation of the soil, the yield under irrigation is large, but unfortunately comparatively few of the farmers possess the requisite water supply and agricultural skill. In many publications on the subject of irrigation, examples of extraordinary success are cited, giving the impression that the majority of farmers attain results as great.

By taking certain counties instead of the state as a whole, and thus eliminating to a large extent the effects of dry farming or of unusual scarcity of water, the results show better the success attained by irrigation. In Weld county, for example, the largest wheat producing county in the state, the average yield of wheat was 24.15 bushels per acre. This unquestionably can be taken as a fair sample of good results by irrigation. For comparison with this may be given, selecting counties at random, Pottawattamie county, Iowa, the average production being 11.54 bushels per acre, and Gage county, Nebraska, where the production was 21.94 bushels per acre. In Weld county the average production of corn was 14.80 bushels per acre, while in Fremont county it was 23.54 bushels per acre. Most of the great corn producing counties of the Mississippi valley have a far larger average production than this. Gage county, Nebraska, for example, averaging in corn 47.49 bushels per acre. The low average in Colorado is evidently due, as previously intimated, to the fact that the corn is not sufficiently watered, if at all. The same thing holds true of oats, for the largest production per acre in irrigated counties is equaled or excelled by other counties taken at random in Indiana, Illinois, and other states.

Comparisons of the staple crops, such as the cereals, do not show such a great advantage for irrigation as might be expected from theoretical considerations. In presenting the benefits of irrigation in popular publications it has been assumed that plenty of water can be obtained, while as a matter of fact this is exceptional. In comparing the returns to the irrigator with those of the farmer well within the Mississippi valley it should not be forgotten that while the irrigator with plenty of water can produce large crops per acre, yet he must pay out a certain amount of money each year for water and spend considerable time in applying the water properly to the crops, compelling him to cultivate a less acreage. Thus it is that although the yield per acre may be greater on the irrigated land, yet on the nonirrigated the farmer can with the same amount of labor and investment cultivate a larger acreage, counterbalancing often the effect of a less profit per acre.

EASTERN COLORADO.

In the eastern part of Colorado, for example, the 32 counties lying east of the principal watershed of the state, comprising 58,135 square miles, or 56.09 per cent of the total area, greater progress has been made than in the portion drained by the Grand and Green rivers, and therefore a number of computations have been made pertaining to these counties as a whole. In the census year there were irrigated in these 32 counties 565,179 acres, or 883.09 square miles, the portion irrigated forming 1.52 per cent of the total area of these counties, a larger proportion than in the entire state. The total number of farms in the 32 counties on June 1, 1890, was 12,014, and of these 5,768, or 48.01 per cent, were irrigated in whole or in part. The total area of the irrigated land on these 5,768 farms was only 30.32 per cent. of the total area owned by the irrigators, and the average size of these irrigated portions was 98 acres. This portion of the state extends from the continental divide on the north and the Sangre de Christo and other mountains in the south, easterly over the Front range, the Wet and other mountains across the plains to Kansas and Nebraska, embracing thus the drainage toward the Missouri river.

The eastern part of the state is divided by a ridge which, starting in the foothills to the east of Pikes Peak, continues easterly nearly across the state, gradually dying down into the Great Plains. This forms the watershed between the two drainage systems of this part of the state, that of the Platte on the north and of the Arkansas on the south. Both of these rivers, rising in many creeks among the high mountains, flow easterly across the plains, furnishing on their course water for hundreds of ditches and canals. The South Platte rises in the South Park nearly in the center of the state and after passing through its lower canyons flows northerly along the base of the mountains, receiving in its course many large perennial mountain streams, each of which issues upon the comparatively level valley land from a deep, narrow canyon. The water is widely distributed, and the streams are of size and slope such that water can be readily diverted from them at small expense. The relative position of the small tributaries of the Arkansas is on the whole less favorable, although by no means presenting great difficulties to irrigation development. The main stream rises west of or behind the South Park and flows southerly and easterly through a long, narrow drainage area, and finally leaving the mountains starts directly across the plains. The larger tributaries from both north and south flow in a general diagonal course toward the river, passing through portions of the plain region, not emptying at once into the main stream, as in the case of the South Platte. Many of them, especially those heading at a considerable distance, thus lose nearly all of their water in passing through these arid regions and contribute little to the river except after heavy storms.

The mountains forming the western edge of the part of the state above mentioned not only give rise to almost innumerable streams, rendering agriculture by irrigation possible at points along their base, but also contain the great stores of mineral wealth which have attracted a large population, furnishing a market for all agricultural products. Thus it is that population and agriculture are concentrated in a comparatively narrow strip from Fort Collins and Greeley on the north, through Denver, Golden, Colorado Springs, Canyon, and Pueblo, to Trinidad on the south. West of this strip are the high mountains from which come the mineral wealth and water, and toward the east stretch the broad plains devoted mainly to cattle raising, but containing many farms upon which crops have been successfully raised without irrigation.

FARMING WITHOUT IRRIGATION.

It must not be supposed that all of the farming in the state is done by means of the artificial application of water. Especially on the eastern border, where there are no living streams, there are counties within which thousands of acres are cultivated annually and from which fair crops are obtained. As stated above a great part of the corn raised within the state is not irrigated and other cereals have been produced in like manner. The yield per acre by the so-called "dry farming" is, as a matter of course, much smaller unless rain happens to fall at times when most needed. Comparing the production of the three leading cereals on irrigated and "dry" farms, it has been found that in the census year in Boulder and 6 adjoining counties the average yield of wheat was 23.62 bushels per acre, while in Phillips, Sedgwick, and Yuma counties, in the northeastern corner of the state, where no irrigation was possible, it was 9.36 bushels per acre, or considerably less than one-half that in the first named counties. A less difference is shown by the oat crop, which in Boulder, Jefferson, Larimer, and Weld counties averaged 30.81 bushels per acre, while in Phillips, Washington, Sedgwick, and Yuma it averaged 17.21 bushels per acre. A still less difference is shown by Indian corn, which in the irrigated counties of Boulder, Jefferson, Larimer, and Weld averaged 15.39 bushels per acre, and in Elbert, Lincoln, Phillips, Washington, Sedgwick, and Yuma averaged 11.57 bushels per acre. Taking Elbert and Lincoln counties alone, where the rainfall is heavier than in the northeastern counties, the average production without irrigation was 21.10 bushels per acre, or larger than in the irrigated counties.

Besides the localities out upon the plains dry farming to a limited extent has been carried on successfully in a few of the higher valleys, where the temperature is low and where there is a relatively large amount of rain. The principal crops are for hay, and most of the cereals when planted are cut for this purpose. Although farming without a water supply has been successful in many places, it should not be inferred that such success is the rule. Hundreds or even thousands of settlers have attempted to make homes for themselves upon the Great Plains and after struggling against the prevailing droughts and losing crops year after year they have been brought to the verge of starvation. The condition of affairs in eastern Colorado has been similar to that in adjoining parts of Kansas and Nebraska. About the years 1886 and 1887 persons attracted by the representations that the soil was wonderfully fertile and the rainfall sufficient for agricultural operations flocked into the country and began to cultivate the soil. During one or two years many were successful and the majority succeeded in raising small crops, but the severe droughts of the succeeding summers caused much suffering and a rapid diminution in population.

ARTESIAN WELLS.

The artesian wells upon the farms in Colorado are found mainly in two great groups, the first of these being in the western end of Arapahoe county, in the vicinity of the city of Denver, and the second, and more important, in San Luis valley, being thus within the counties of Conejos, Costilla, Rio Grande, and Saguache. Outside of these areas many deep wells have been drilled, in some instances obtaining flowing water in small quantities. These latter wells have been put down usually by municipalities or corporations in search of water for city supply or similar purposes, and have little or no importance in irrigation.

In Arapahoe county 185 flowing wells upon farms have been enumerated, the depth ranging from 136 feet to 858 feet, the average being 400 feet. The average cost of these was $420 and the discharge 13 gallons per minute. Comparatively a small amount of this water was used for irrigation, but for each well thus employed an average of 3 acres was irrigated. Most of the wells were drilled or driven for the purpose of obtaining water for domestic purposes, as it is far preferable to that obtained from the surface.

The flowing wells are mainly found within an area which begins about 15 miles south of Denver and extends northerly along the South Platte river for about 40 miles. The principal places within the artesian basin are, besides the city of Denver, Littleton, Petersburg, Island Station, and Brighton. The geological structure of this basis has been described by several writers, and the statistics regarding the artesian wells have been tabulated in detail. Among the first of the descriptions is that given in 1882 in a report upon the artesian wells upon the Great Plains by C. A. White and Samuel Aughey. This report, which covers the general subject of artesian wells upon the Great Plains east of the Rocky mountains, was written before the discovery of flowing water at Denver in 1883. A report upon the artesian wells of Denver, prepared by Whitman Cross and others, was published by the Colorado Scientific Society in 1884, as was also at a later date a second report upon the same subject, prepared by Charles G. Slack. This latter is an abstract of materials collected for use in the monograph upon the geology of the Denver basin by S. F. Emmons.

Besides the reports prepared by Emmons, Cross, White, and other members of the United States Geological Survey, statistics have been collected by other persons, notably by L. G. Carpenter of the State Agricultural College of Colorado, these being printed in reports to the Department of Agriculture and in Bulletin No. 16 of the agricultural experiment station of Colorado. This matter having been so thoroughly discussed in print it is not necessary to enter into further description. It is sufficient to state that the wells penetrate several alternations of clay and sandstone, most of the latter rocks containing water under hydrostatic pressure so great that it rises to the surface.

The number of wells in the basin, especially in the vicinity of Denver, has increased so rapidly that it has resulted in a less discharge than formerly from the older wells. In the city it is plainly seen that the opening or closing of one well affects those in the immediate neighborhood, but in the country this is not so apparent. In some cases the flow has entirely ceased, due either to this cause or to the clogging of the well by sand, or by losing water through some defect in the mechanical construction of the well. The water is generally soft and palatable and well adapted for domestic use. The quantity from any one well is so small that it is difficult to use it effectively for irrigation without the construction of reservoirs in which the water can accumulate until there is sufficient to give the field to be irrigated a complete saturation.

Northeast of the Denver basin, in Weld county, a few deep wells have been drilled by towns for the purpose of obtaining water for general uses. In a few instances the water rises to the surface and flows at the rate of a gallon or more a minute. One of these wells, at Greeley, is reported to be over 2,250 feet deep, and others in the same place and at Evans are about 1,200 feet. The amount of water from the wells which flow is so small that it can not be considered as a factor in irrigation, especially in view of the great expense involved in obtaining it. A few flowing wells are found in Jefferson county, where the water is used to a small extent on gardens. The flow, however, has decreased greatly, and in some instances stopped, so that it is necessary to use windmills to bring the water to the surface.

At Longmont, in Boulder county, 30 miles north of Denver, attempts have been made to secure flowing wells, and also at Loveland, in Larimer county, 45 miles north of Denver, where a well was put down to the depth of over 2,450 feet, but without success.

Toward the southern part of the state, near the base of the Rocky mountains, several deep wells have been drilled, notably in the vicinity of Pueblo. The first well was bored in 1879 for petroleum and reached a total depth of 1,400 feet. At a depth of 1,180 feet water of mineral character, and having a temperature of 80 degrees fahrenheit, was found. This discharged at the rate of about one-quarter of a second-foot, or a little over 100 gallons per minute. Other wells have been drilled in the vicinity of Pueblo, but the water, so far as can be ascertained, has not been used for agricultural purposes. West of Pueblo, in Fremont county, near Florence and Canyon city, a large number of wells have been drilled for the purpose of obtaining petroleum. Many of these wells would discharge water more or less mineral in character if this were not shut off by packers. In the western part of the state deep drillings are reported at several towns, and also a flowing well at Montrose, in the county of the same name. No artesian wells, however, are reported by farmers.

In the eastern end of the state, in the counties far out on the Great Plains, large sums have been expended in the attempt to secure artesian water. Deep wells have been sunk by railroad companies and other corporations, by towns, and in two instances by the national government under the direction of the Department of Agriculture. At Akron, in Washington county, the water in the government well rose to within 55 feet of the surface. At Otis, about 12 miles east, a well 2,400 feet deep did not reach flowing water. In Cheyenne county, at Cheyenne Wells, 2 deep wells were sunk without finding flowing water. One of these, an experimental drilling by the government, reached a depth of 1,740 feet. At Kit Carson, 25 miles westerly from this point, a well has been drilled to the depth of 1,300 feet, but without success. At Sheridan lake, in Kiowa county, about 25 miles southerly from Cheyenne Wells, deep drillings have also been unsuccessful. At Fort Lyon, near Las Animas, in Bent county, the government well, over 700 feet in depth, was unsuccessful. East of this point, in Prowers county, there are reported to be a number of small flowing wells along the Arkansas river, the depth being given as about 230 feet.

The great artesian basin of Colorado is in San Luis valley, flowing water being found at almost every point within the limits of the ancient lake bottom. The largest flowing wells are those in the vicinity of the town of Alamosa, the greater part of the water coming from a depth of 600 to 800 feet. The average depth of all the wells in the basin is only about 200 feet, and the cost was approximately $150 each. The discharge, taking large and small together, averages 53 gallons per minute. A trifle over one-half the wells on the farms have been used for irrigation, watering an average of 17 acres each. This gives a water duty of approximately 1 second-foot to 144 acres.

In Conejos county the flowing wells are mainly in the northeastern corner, from La Jara to Alamosa. They vary in depth from 40 to 478 feet. The shallower wells yield a cold, palatable water, but that from the deeper wells is considered too warm for drinking. This latter class of wells is more valuable for irrigation on account of the higher temperature of the water, since it does not chill the plants. Many of the farmers report attempts at irrigation, but state that with the small shallow wells possessed by them these have not been successful, as the wells discharge such a small quantity of water that it can not be utilized except by the construction of reservoirs, which would impose additional expense. Other farmers, where the surface of the ground is favorable, have constructed small earth reservoirs in which the water can accumulate until warmed by the sun in an amount sufficient to render irrigation practicable.

There is general complaint that the water is allowed to run to waste and that some of the neighboring wells have been injured thereby. There is clearly a general diminution in discharge, although this is not seen in all the wells, especially in the case of those in the thinly settled country. In the latter part of the crop season, when the small ditches of the farmers become nearly or quite dry, the flowing wells are of especial benefit, since the need of even a small amount of water at that critical time is imperative. In a few cases the water is so strongly impregnated with mineral matter that the farmers have not been successful in employing it for irrigation, but these instances are comparatively rare, and the well and river waters are often used together.

In Costilla county the majority of the wells are in the northern and western part, on the lands irrigated by the large canals from the Rio Grande. The water, as in the case of the other counties, is used mainly for houses, gardens, and for stock, since most of the farmers have an ample supply for irrigation from the ditches which traverse the county in various directions. Some of the wells, however, are used in this manner, but it is stated that away from the vicinity of ditches the wells are of comparatively little use in irrigation, for the reason that where the ground is perfectly dry to the depth of 6 or 8 feet or more, the small amount of water from an ordinary flowing well is completely lost before it can cover an area of any considerable size.

In and near Alamosa are several flowing wells which have attracted considerable attention from the fact that when properly regulated one at least will throw water to the height of upward of 40 feet, and when flowing freely will discharge as high as 1 cubic foot per second. The water from some of these wells is run into depressions, and ponds have been made in which the raising of fish has been begun, and it is possible that enterprises of this character may prove profitable in a small way.

In Rio Grande county the flowing wells are found mainly in the eastern end, near Monte Vista and other towns. Very few of the farmers use this water for irrigation on account of the fact that it is too cold and clear, not carrying the fine silt of river water. Exposing the artesian water in reservoirs, so that the sun will warm it, has not been tried to any considerable extent. Nearly all the wells have been put down for household uses, since most of the farmers have an ample supply for irrigation. The flow has not diminished by any notable amount.

In Saguache county the flowing wells are widely distributed in the eastern and southern parts of the county. As in the case of the other counties, they were drilled or the pipe was driven for the purpose primarily of obtaining pure water for household use, especially in winter, and at such other times as the irrigating canals were not filled. The wells at first sunk were quite expensive, but at the present time they are put down very cheaply, the current price given being 30 cents a foot for a 3-inch well and 50 cents a foot for one 6 inches in diameter. The cost of many of the wells is very small, from the fact that it has been found that wells will flow without the use of casing, excepting one or two joints at the top sufficiently long to reach into the thick beds of clay. The clay is so cohesive that it forms the wall of the well and does not fall in or become pressed out of place. The practice of not using casing, however, is in general to be condemned, from the fact that if several layers of porous sands or gravels happen to be encountered in sinking the well the water of one of them could pass freely into another and possibly be lost, not only injuring that particular well, but diminishing the supply for the whole neighborhood.

The pressure of the water in most of the wells has decreased somewhat, and from all the evidence presented is probably diminishing gradually as other wells are sunk. The small expense of procuring the flowing water is favorable to the rapid development of the artesian area, in spite of the fact that many of the settlers are poor. As more of this fertile valley land is brought under cultivation and new homes are built the flowing wells are multiplied, so that it is only a question of a short time when measures must be enforced to prevent waste in order that all may not suffer.

CONDITION OF IRRIGATION IN EACH COUNTY.

The distribution of irrigation in the various counties is shown by the following table, which gives the number of irrigators, the area irrigated, and the average size of the farms, or rather of the portions of farms, on which irrigation was practiced. This is followed in turn by a general description of the condition of agriculture in each of these counties.

NUMBER OF IRRIGATORS, AREA IRRIGATED, FARMS, AND CROPS IN COLORADO IN 1889, BY COUNTIES.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.	OWNERS OF FARMS. (a)		IRRIGATORS.		Area of counties in acres.	FARM AREA.		Cereals. (Acres.)	Alfalfa. (Acres.)	AREA IRRIGATED.		
				Total number.	Per cent of population.	Per cent of farm owners.	Per cent of population.		Acres.	Per cent improved.			Per cent of area of county.	Per cent of total farm area.	Per cent of land owned by irrigators.
Total	9,650	890,735	92	16,389	3.98	58.94	2.34	66,332,800	4,598,941	39.65	851,086	126,531	1.34	19.37	31.09
Arapahoe	520	35,619	68	1,780	1.35	29.21	0.39	3,340,800	437,433	83.20	33,708	15,626	1.07	8.14	29.20
Archuleta	45	3,084	69	59	7.14	76.27	5.45	704,000	9,781	44.01	676	72	0.44	31.53	33.73
Baca	2	60	30	310	20.96	0.65	0.14	1,472,000	63,401	25.75	1,187	11	0.00	0.09	18.74
Bent	83	4,221	51	120	9.14	69.17	6.32	960,000	30,058	41.06	1,983	1,834	0.44	14.04	15.88
Boulder	449	70,962	158	463	3.29	96.98	3.19	505,000	107,857	86.37	30,543	10,426	14.04	65.79	66.54
Chaffee	148	11,994	81	151	2.28	98.01	2.24	736,000	28,996	50.02	3,956	732	1.63	41.36	41.25
Cheyenne	....	....	....	49	9.18	....	....	1,152,000	8,829	24.87	640	1	....	....	....
Clear Creek	12	352	29	13	0.18	92.31	0.17	249,600	5,899	16.99	....	....	0.14	5.97	5.96
Conejos	387	46,273	120	398	5.53	97.24	5.38	768,000	87,589	63.99	10,602	53	6.03	52.83	52.29
Costilla	196	25,918	132	207	5.93	94.69	5.61	1,100,800	64,749	88.78	4,770	333	2.35	40.03	39.83
Custer	221	20,997	95	325	10.94	68.00	7.44	460,800	79,847	30.46	5,663	432	4.56	26.30	32.87
Delta	312	17,846	57	313	12.35	99.68	12.31	736,000	50,763	38.60	5,032	4,235	2.42	35.16	35.03
Dolores	12	216	18	18	1.20	66.67	0.80	640,000	2,800	10.46	27	....	0.03	7.71	11.25
Douglas	96	5,699	59	347	11.54	27.67	3.19	537,600	292,726	6.80	3,726	1,811	1.06	1.95	4.29
Eagle	176	14,250	81	187	5.02	94.12	4.72	1,024,000	37,541	45.08	2,404	932	1.39	37.96	37.92
Elbert	32	2,616	82	303	16.33	10.56	1.72	1,203,200	157,203	19.97	2,623	2,877	0.22	1.66	6.14
El Paso	139	10,959	79	531	2.50	26.18	0.65	1,702,400	281,669	45.22	8,857	2,388	0.64	3.89	8.46
Fremont	312	13,508	43	324	3.54	96.30	3.41	1,024,000	52,868	33.06	8,872	2,211	1.32	25.55	24.57
Garfield	314	14,637	47	327	7.30	96.02	7.01	2,080,000	54,323	31.66	3,099	1,075	0.70	26.94	26.82
Gilpin	....	....	....	35	0.60	....	....	96,000	7,986	30.92	....	265	....	....	....
Grand	98	10,281	105	105	17.38	93.33	16.23	1,344,000	27,768	53.69	3	....	0.70	37.02	37.02
Gunnison	165	20,115	122	176	4.04	93.75	3.79	2,048,000	37,329	62.21	198	9	0.98	53.89	53.91
Hinsdale	19	1,389	73	27	3.13	70.37	2.20	896,000	5,008	66.21	....	....	0.16	27.74	36.72
Huerfano	400	22,294	56	517	7.51	77.37	5.81	1,024,000	116,415	35.57	4,629	2,144	2.18	19.15	21.83
Jefferson	470	40,829	87	783	9.27	60.03	5.66	550,400	171,304	48.27	12,160	12,291	7.42	23.83	44.86
Kiowa	....	....	....	170	13.68	....	....	1,152,000	28,612	22.76	1,974	2	....	....	....
Kit Carson	....	....	....	305	12.34	....	....	1,376,000	62,966	20.86	6,171	....	....	....	....
Lake	36	6,591	183	41	0.28	87.80	0.25	288,000	13,973	62.91	51	....	2.29	47.17	48.65
La Plata	230	11,785	51	295	5.35	77.97	4.17	1,190,400	56,220	31.39	3,885	2,518	0.99	20.96	23.16
Larimer	769	103,483	135	845	8.70	91.01	7.92	2,624,000	272,918	53.01	38,869	8,787	3.94	37.92	39.97
Las Animas	353	22,891	65	630	3.66	56.03	2.05	3,068,000	166,960	37.34	4,274	3,001	0.76	13.71	22.57
Lincoln	5	334	67	98	14.22	5.10	0.73	1,664,000	26,066	16.53	647	100	0.02	1.28	5.66
Logan	73	8,970	123	248	8.08	29.44	2.38	1,171,200	63,399	55.16	4,971	2,013	0.77	14.15	27.89
Mesa	310	13,798	45	321	7.54	96.57	7.28	1,920,000	48,680	43.49	5,901	4,107	0.72	28.34	28.29
Montezuma	29	2,122	73	35	2.29	82.86	1.90	1,689,600	7,039	63.83	402	708	0.13	30.15	30.14

a Includes owned and hired farms, assuming one farmer to each.

NUMBER OF IRRIGATORS, AREA IRRIGATED, FARMS, AND CROPS IN COLORADO IN 1889, BY COUNTIES—Continued.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.	OWNERS OF FARMS.		IRRIGATORS.		Area of counties in acres.	FARM AREA.		Cereals. (Acres.)	Alfalfa. (Acres.)	AREA IRRIGATED.		
				Total number.	Per cent of population.	Per cent of farm owners.	Per cent of population.		Acres.	Per cent improved.			Per cent of area of county.	Per cent of total farm area.	Per cent of land owned by irrigators.
Montrose	462	27,361	59	569	14.30	81.20	11.61	1,472,000	103,345	35.36	9,083	7,659	1.86	26.48	31.88
Morgan	97	16,443	170	147	9.18	65.99	6.06	825,600	52,106	42.14	2,643	2,823	1.99	31.56	37.90
Otero	139	16,431	118	177	4.22	78.53	3.32	1,312,000	61,347	40.72	3,417	4,988	1.25	26.78	31.01
Ouray	94	7,894	84	96	1.47	97.92	1.44	288,000	16,998	59.86	2,539	583	2.74	46.44	46.35
Park	136	24,015	177	171	4.82	79.53	3.83	1,344,000	120,567	36.76	384	....	1.70	19.92	20.75
Phillips	....	....	....	408	15.44	....	....	364,800	94,302	26.82	10,061	....	....	....	....
Pitkin	115	7,041	61	116	1.30	99.14	1.29	608,000	21,068	40.07	1,981	456	1.16	33.42	32.98
Prowers	18	1,808	100	101	5.13	17.82	0.91	1,056,000	46,447	20.92	654	257	0.17	3.89	22.32
Pueblo	206	10,930	53	325	1.03	63.38	0.65	1,536,000	100,697	48.17	2,838	3,372	0.71	10.85	16.93
Rio Blanco	135	7,532	56	191	15.92	70.68	11.25	2,304,000	36,675	47.33	1,366	157	0.33	20.54	21.00
Rio Grande	195	21,707	112	198	5.74	98.48	5.65	806,400	55,793	59.11	7,817	311	2.[illegible]	39.07	39.07
Routt	280	16,323	58	367	15.49	76.29	11.82	3,840,000	93,872	59.08	577	339	0.[illegible]	17.3[illegible]	19.38
Saguache	240	52,453	219	262	7.91	91.60	7.24	2,073,600	200,587	25.24	4,267	392	2.[illegible]	26.15	25.90
San Juan	....	....	....	....	....	....	....	320,000	....	....	....	....	....	....	....
San Miguel	57	2,125	37	88	3.03	64.77	1.96	832,000	15,768	28.30	140	30	0.26	13.48	16.96
Sedgwick	....	....	....	280	21.66	....	....	416,000	52,724	78.94	6,615	....	....	....	....
Summit	20	1,316	66	20	1.05	100.00	1.05	441,600	3,680	63.53	22	....	0.30	35.76	35.76
Washington	1	720	720	356	15.47	0.28	0.04	691,200	77,341	28.35	11,762	42	0.10	0.93	90.00
Weld	1,046	112,080	107	1,225	10.44	85.39	8.91	2,608,000	368,781	55.15	65,495	24,380	4.30	30.39	43.29
Yuma	5	373	75	436	16.80	1.15	0.19	755,200	109,870	30.07	17,022	248	0.05	0.34	4.17

ARAPAHOE COUNTY comprises a long, narrow strip of land in the northeastern part of Colorado, extending nearly half across the state. In the extreme western end is the city of Denver, and the county stretches east to the Kansas line. Nearly all of the irrigated land is along the South Platte, which flows northerly through Denver. Many large canals take water out from this river or from the tributaries coming in from the west, the principal of which are Bear and Clear creeks. East of the river are many streams crossing the county from south to north and finally emptying into the South Platte, but most of these only carry water during times of flood, and are dry during the summer. Many attempts have been made to raise crops throughout the eastern part of the county. The soil is rich, but the rainfall is very uncertain. By careful cultivation, some crops are profitable, but there is little certainty owing to the prevailing summer droughts. Near the Kansas line, corn, oats, wheat, barley, and potatoes are raised, but the yield per acre is sometimes less than half that on irrigated land. Many settlers have tried for two or three years, but their attempts at farming have been so discouraging in the results attained that they have either left or are trying to make a living by raising stock. Water in many places can be obtained only by wells of from 80 to 200 feet in depth.

The south fork of the Republican river and its principal tributary, the Arikaree, flow diagonally across the eastern end of the county, furnishing a small amount of water for irrigation, the ditches being very small and taking water to the ranches of one or two individuals. In the Arikaree valley the crops during the census year were fairly good considering the prevailing drought. On the high, level divides between the streams farmers have not been as a rule successful, and it is stated that the surrounding country is fast decreasing in population.

The canals in the vicinity of Denver are among the largest in the arid regions. Taking them in general geographical order, the first of importance on the east side of the South Platte is the Northern Colorado Irrigating Company's canal, which heads in Douglas county and covers lands east of Denver. Below this are the Platte Water Company's ditch and many smaller ditches taking water from Dry creek, Little Dry creek, and Cherry creek. North of the city, and on the east side of the river, are the Burlington, the Duggan, and the Fulton, the latter extending beyond Fort Lupton in Weld county. On the west side of the South Platte in this county are the Last Chance and Nevada ditches, taking water from the river, and the Agricultural ditch, taking water from Clear creek below Golden, besides a number of small ditches depending upon Bear creek for their supply. North of Denver are the ditches from Clear creek, the most important of these being the Colorado Agricultural ditch and the Clear Creek and Platte River ditch. The aggregate capacity of the canals and ditches exceeds the water supply, and except in times of flood some of the canals can not be filled. There is more or less complaint that owing to lack of restrictions speculators have built canals and sold water rights which are practically valueless.

The Northern Colorado Irrigating Company's canal, known as the Platte canal, or more commonly the "Highline", heads in the Platte canyon, about 20 miles above Denver, and covers lands on the east side of the river in the vicinity of the city. The total length with the Sand Creek branch is 85 miles, and the average width for the first 50 miles is nearly 40 feet. The grade is 21 inches to the mile and the average depth of water 4 feet. The total cost was $650,000. The canal was begun in 1879 and used in 1883. Water is diverted by a dam 120 feet long and 14 feet high, made of heavy timbers and provided with a masonry wasteway. There are about 200 laterals, each from one-half mile to 6 miles in length, and all belonging to farmers. Water rights in this canal have sold for from $35 to $40 per acre. The annual assessment, $1.75 per acre, is that established by the county commissioners. The water supply is usually short once or twice during the season, owing partly to the fact that it is taken by other canals and ditches, although these do not have prior rights to it. (*a*)

The city ditch heads below the canal just described on the same side and runs along the east bank of the river, carrying water to the city of Denver. It is 28 miles long, 10 feet wide, and cost about $65,000. It was begun in 1859 and used in 1865. The canal is owned by the city of Denver, which purchased the entire control for the purpose of supplying water to the gutters of the streets of the city, thus irrigating the trees and parking along the sides. Until the construction of the Highline ditch it was the most important work of its kind east of the Platte river.

The Agricultural ditch takes water from Clear creek out upon the lands on the south side and runs in a southeasterly direction, ending at the Platte river at a point 7 miles south of and above Denver. The total length of the ditch is 25 miles, the average width 8 feet, and the cost was $50,000. It was begun in 1874 and used in the following year. It is owned by a company and the water is divided among the shareholders.

ARCHULETA COUNTY lies west of the continental divide and adjoins Rio Arriba county, New Mexico. It contains a comparatively small amount of agricultural land and has a large, well distributed water supply. The population is small and scattered, mining and stock raising being the principal industries. Nearly all crops can be raised without irrigation, although with water applied at the proper time the yield is increased. The San Juan river and its tributaries flow across this county, carrying at all times a large quantity of water, the amount of which has not been measured. Along each of these streams one or more ditches have been taken out for irrigating grass and other crops finding a ready market at the mining camps. This part of the state, however, is so remote from large markets and the expense of transportation is so great that the development of agriculture must be slow. Surveys have been made for ditches of from 4 to 10 miles in length to irrigate lands in the vicinity of Pagosa Springs. The expense of construction in this mountainous country is great and progress of necessity is not rapid.

BACA COUNTY is in the southeastern corner of Colorado, adjoining Kansas and the public land strip. It is thus far out in the Great Plain region and on a part of it where the water supply is unusually small. The Cimarron river cuts across the southeastern corner, furnishing a small amount of water which can be diverted by ditches to the ranches on the bottom land. The northern part of the county is crossed by the drainage channel of Two Butte creek, which leads into the Arkansas, and by that of Horse creek and other tributaries of Bear creek, which, continuing easterly into Kansas, is lost in sinks among the sand hills. There is very little water in these channels except after heavy rains.

The population of the county is scattered, about the only occupation being stock raising. In 1887 there was an influx of settlers, but many of these left during the succeeding years on account of drought. The principal part of the area in cereals was devoted to Indian corn, besides this there being some sorghum and vegetables raised. A large part of the surface of the county is covered by sand hills, and the agricultural possibilities appear to be small.

BENT COUNTY is northwest of Baca, including lands on both sides of the Arkansas river. Within this county are several large canals, which have been extended from Pueblo and Otero counties on the east, and also a few ditches deriving water from the Arkansas within the county limits and covering lands in the vicinity of Las Animas. Many of the farmers, depending for their supply upon the large canals, complain that at this distance from the head they have not been able to obtain a sufficient amount of water, having only one-half or three-quarters the quantity for which they have paid. For this reason they state that they have been afraid to make many improvements, such as setting out orchards. There is a demand that the canal companies be prevented in some way from selling water rights unless there is reasonable assurance that the quantity of water called for can be delivered. Agriculture in this and the adjoining counties has been but lately developed. In 1887 and 1888 only a few acres were cultivated, the principal industry being the raising of cattle and horses. By the construction of the large canals, however, agriculture is rapidly advancing, the chief drawback being, as previously intimated, the uncertainty regarding the ability of the canal companies to keep the system in repair and furnish water at all times.

Measurements of the amount of water in Las Animas river, which flows into the Arkansas near the town of Las Animas, were made during 1889, giving the results shown in the table on the following page. This stream is also known as the Purgatoire or, in common parlance, the Picket Wire. It is a stream which near its head waters is of considerable importance, but the portion of its drainage channel traversing the plains region does not receive a perennial supply of water and through a great part of the year is completely dry.

---

a For a more complete description and a view in the canyon see a paper by H. M. Wilson on American irrigation engineering, Transactions American Society of Civil Engineers, volume 25, pages 117-119.

DISCHARGE OF THE LAS ANIMAS OR PURGATOIRE RIVER AT LAS ANIMAS, COLORADO.

(Drainage area, 3,040 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
May 22 to 31	55	11	22	1,353	0.01	0.01
June	170	27	70	4,165	0.03	0.02
July	1,770	8	260	15,990	0.10	0.09
August	780	6	69	4,243	0.03	0.02
September	275	6	40	2,380	0.01	0.01

BOULDER COUNTY is in northern Colorado, northwesterly from Arapahoe county. It extends from the summits of the Front range easterly to the plains, and thus comprises on its western side a high catchment area from which a large amount of water comes, and on the east many thousand acres of fertile land upon which the water is used. The facilities for irrigation are almost unrivaled, and the county contains the largest proportion of irrigated land of any county in the United States, amounting to 14.04 per cent of the total area.

The boundaries of the county are so located as to include nearly all of the drainage basin of St. Vrain creek and of its principal tributary, Boulder creek. These streams are formed by the union of a number of torrents, each of which is fed principally by melting snows in the mountains. At and below the point where these creeks leave the canyons and enter upon the plains are the headworks of many irrigating canals and ditches, taking the water out upon each side and forming a network over the country. The slope of the land surface and of the streams is sufficiently great to allow the canals to be carried back almost at right angles to the source of supply, thus covering the land between the two tributaries. So many systems of irrigation have been constructed that it is impossible to fill all with water, and during the summer some of the ditches are nearly dry, thus resulting in more or less loss to the farmers. Each year more land is brought under cultivation than can be satisfactorily irrigated unless there is an exceptional amount of snow in the mountains.

To supply the deficiency of water during the summer season many depressions in the surface have been utilized as reservoirs in which flood waters are stored. These are comparatively few in number and by no means sufficient for the needs of the farmers. It will be necessary to make use of every facility for water storage not only near the lands to be irrigated but also higher in the mountains, in order to greatly increase the area irrigated. Even when this is done it is doubtful whether all of the arable land of the county can be cultivated each year. The farmers complain that ditches are being built or enlarged partly for speculative purposes, and they do not believe it right to encourage the extension of irrigation until water is provided for the lands now cultivated. In many instances they state that they can not follow any system in the application of water to the soil, from the fact that they must use the water at times when they can get it, rather than when the plants need moisture.

St. Vrain creek and its tributaries, with the exception of Boulder creek, form water district No. 5, the lower portion of this being in Weld county. In this district it is stated that the amount of water decreed to the various ditches is over nine times the average discharge of the creek during the irrigating season; in other words, if the water is divided equally each ditch must receive less than one-ninth of the water to which it is apparently entitled. In the report of the water commissioner for this district 61 ditches are enumerated, having an aggregate length of 244 miles. The drainage basin of Boulder creek forms district No. 6, which also extends into Weld county. The 60 ditches given in this district have a total length of 258 miles.

The principal irrigating ditches in the county are as follows: on the north side of St. Vrain creek are Supply, Highland, Rough and Ready, St. Vrain and Palmerston, Longmont Supply, Chatman, Oligarchy, Demio and Taylor, and the Farmer ditches. On the south side of St. Vrain creek are South Ledge, Swede, James, Pella, Niwot, South Flat, and the Bonus ditches. On the north side of Lefthand creek are Tollgate, Table Mountain, Badger, Holland, Cochran, and Williamson ditches. On the south side of Lefthand creek are Altoona, Crocker, Badger No. 2, Johnson, Star, Farmers, Hornbaker, and other ditches. On the north side of North Boulder creek are the Farmers, Boulder and Whiterock, Boulder and Lefthand, Revolution and Legget. Between North and South Boulder creeks are the McIntosh, Dry Creek, and Howard ditches, taking water from South Boulder creek. On the south or east side of this latter creek are the South Boulder and Coal creek, Community, Davidson, Goodhue, Marshallville, Doggett, Dry creek, Cottonwood, Barter, Lower Boulder, Matthews, and other ditches. A description of a few of these will serve to give the general character.

The Highland ditch, on the north side of St. Vrain creek, is about 35 miles long, 15 feet wide, and cost $40,000. It was built in 1871 and partially used in the following year. The water supply is insufficient, but it is to be increased by the use of reservoirs, filled in April and May and utilized in the latter part of June and July. The present selling value of the water rights is stated to be about $20 per acre. The Rough and Ready ditch, below this and in a general way parallel to it, is 15 miles long, about 12 feet wide, and cost nearly $10,000. The value of water right per acre is stated to be about $10. Attempts are being made to increase the water supply by storage reservoirs, since a large amount of grain is lost each year under this, as well as under other ditches, because of scarcity of water. The Oligarchy ditch is about 15 miles long, 12 feet wide, and cost $6,000. It is owned by farmers using the water. As in the case of the other ditches, there is complaint of scarcity of supply. The Boulder and Whiterock ditch is about 25 miles long and cost $35,000. It was begun in 1873 and used in 1874.

CHAFFEE COUNTY is about the center of the state, lying between the Park range on the east and the Saguache mountains on the west. It is near the head waters of the Arkansas river, this stream rising to the north in Park county and flowing southerly through Chaffee and Fremont counties to the Great Plains. The general altitude of the agricultural lands in the valley is from 7,000 to 9,000 feet, these extending along the Arkansas and its principal tributaries. The streams which come from the mountains on each side of the county are utilized for irrigation by many ditches. A map published by the state engineer and covering the irrigated portion of this county shows nearly 150 of these. No crops are raised without irrigation on account of the deficiency of moisture during the summer. The supply of water in the streams, however, is usually good, although there is necessity each year for careful division of it during the summer. Nearly all cereals and vegetables are raised, the altitude being in most places too high for the success of corn and many fruits. Most of the water, however, is used for producing hay or on the meadows and other pasture lands.

The amount of water available for irrigation has been measured at a few points in Lake county (which see) and also within this county. Gaugings of Clear creek were made near Granite from April to October, 1890, showing that the maximum discharge was 435 second-feet and the minimum 12 second-feet, the average for this time being about 133 second-feet. The drainage area at the point where measured is 72 square miles. Both the middle and south forks of the Cottonwood were gauged near their junction west of Buena Vista, the observations continuing from April to August. The average discharge of the middle fork was 65 second-feet and of the south fork 71 second-feet. These measurements were made by the United States Geological Survey for the purpose largely of determining the value of these streams for storage purposes.

For the needs of the county itself there is comparatively small demand for water storage, but there is great necessity for holding at these high altitudes as much of the flood water as possible for the dry lands farther down the river on the Great Plains. There are, however, a number of small projects undertaken by irrigators in this county having in view the saving of water for their own use during the summer, and work has already been begun on small reservoirs. Taking the county as a whole there is probably greater need of more careful use of the water available than there is of increasing the amount by storage.

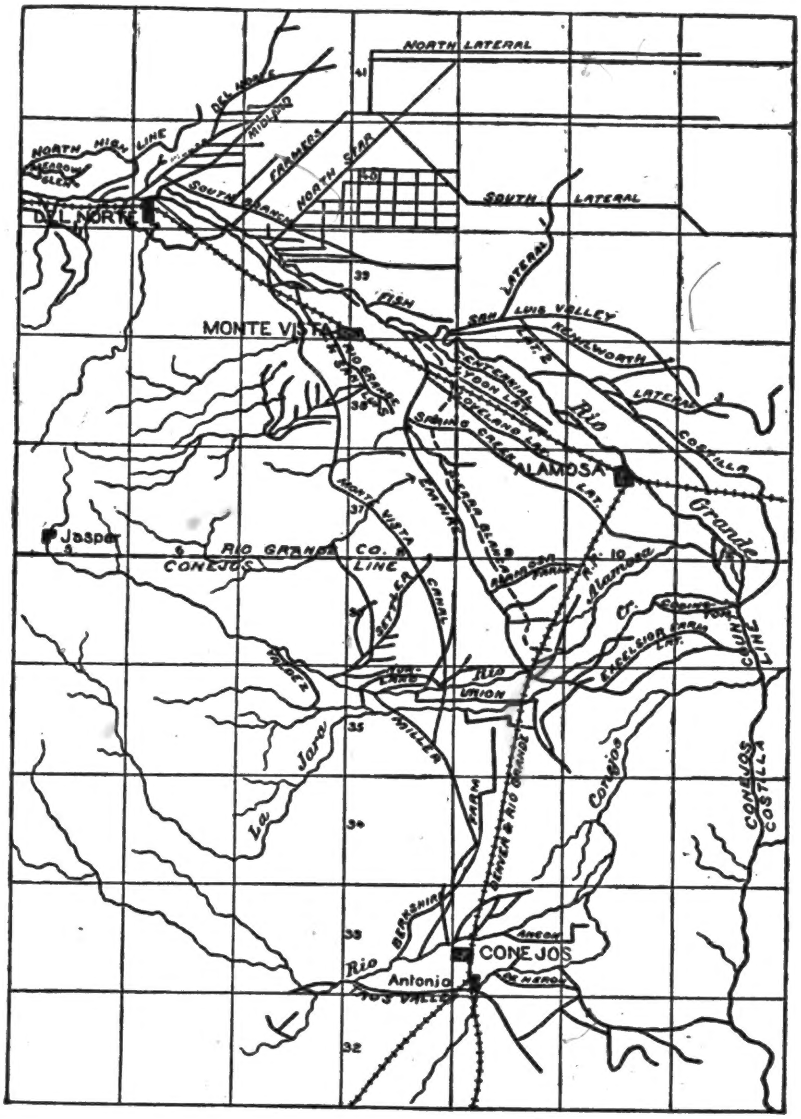
Among the principal ditches of the county may be mentioned the Missouri Park ditch, taking water from the South Arkansas and carrying it out on the north side northeasterly to the valley of the Arkansas. It is about 4 miles long, 10 feet wide, and cost about $5,000. It was begun in 1880 and used in 1882. Below this is the Hill and Sprague ditch, coming out on the same side and in a parallel direction. It is about 6 miles long, 4 feet wide, and is owned by private parties. The Willowdale ditch takes water from Chalk creek out on the south side of the valley. It is about 5 miles long, 6 feet wide, and cost $2,500. It is owned by private parties and irrigates about 250 acres. From all sources of water supply there are to be found many little ditches running in nearly parallel courses, a number of which might be replaced by one good canal carrying water to the land with less loss and greater efficiency.

CHEYENNE COUNTY is on the eastern side of the state. It is far out on the Great Plains and may be taken as a fair representative of the counties within this almost arid region, where cattle raising is the principal industry. Few crops can be produced without irrigation, and for this latter method of agriculture there is almost no water supply. Farming without the application of water has been tried and in some localities has been partly successful. Fruit trees have been set out as an experiment, and many of these survived the drought of 1890. Sorghum has been cultivated, but with little success. Big Sandy creek and its tributary, Rush creek, are in the western end of the county, but these seldom have any water in the channel except that which may be percolating through sandy beds. Occasionally after a heavy storm these creeks and the dry arroyos become torrents for a few hours, the flood quickly disappearing. In the eastern end of the county are the head waters of the Smoky Hill river, which, rising in springs, flows easterly. The amount of water in these is almost insignificant, and it is soon evaporated or lost. Attempts have been made to secure water by means of wells. The town of Cheyenne Wells is supplied by a steam pump drawing from a well 256 feet deep. Within 5 miles there are two other wells, one 250 feet, the other 200 feet in depth, both of these being pumped by windmills. At other parts of the county water is obtained at less depths and in quantities sufficient for cattle. The soil, as usual on the prairie, is rich, and with sufficient rainfall produces large crops, but unfortunately there are comparatively few years during which the precipitation is heavy.

Clear Creek county covers a small area of the eastern slopes of the Front range west of the city of Denver. It consists largely of high mountains with narrow valleys, and is notable for its mineral wealth. There is very little land favorable for agriculture, and the altitude is too great for the success of most crops, Georgetown, the county seat, being at an elevation of 8,484 feet. Along the creek below Georgetown small areas of land have been brought under irrigation, mainly for the purpose of raising hay.

Conejos county is on the south side of the state, west of the Rio Grande, and between it and the summits of the San Juan mountains. It thus includes the southwestern portion of San Luis park and adjacent watershed. The altitude of Alamosa is 7,531 feet, and of the town of Conejos 7,880. The principal agricultural land of the valley is between or in the vicinity of these places, and thus is at an elevation higher than that at which many of the crops of the temperate zone are ordinarily raised. The climate, however, is relatively mild, and the yield of the cereals and forage crops is large, as is the case throughout this valley. The water supply of the county is unusually good, a number of large streams coming out from among the San Juan mountains. The principal of these are Alamosa, Lajara, Conejos, Pinos, and San Antonio creeks. All of these on reaching the valley rapidly change in character from mountain torrents and apparently lose a large proportion of their waters in the pervious bottom lands. The larger streams cross the low lands and flow into the Rio Grande, while others do not contribute water to this river except at flood times. Few ditches are taken from the Rio Grande in this county on account of the difficulty of diverting water, but there are a number of large canals, mainly in Rio Grande county, which extend

MAP OF PRINCIPAL IRRIGATING CANALS OF CONEJOS AND RIO GRANDE COUNTIES, COLORADO.


NORTH LATERAL
41
DEL NORTE
MIDLAND
NORTH HIGH LINE
MEADOW GLEN
FARMERS
NORTH STAR
SOUTH BRANCH
150
SOUTH LATERAL
DEL NORTE
LATERAL
39
FISH
SAN LUIS VALLEY
LAT. 2
KENILWORTH
MONTE VISTA
RIO GRANDE
38
CENTENNIAL
LYDON LAT.
LOVELAND LAT.
SPRING CREEK
LATERAL
Rio
COSTILLA
ALAMOSA
LAT.
MONTE VISTA
EMPIRE
SIERRA BLANCA
37
Grande
Jasper
5
6
RIO GRANDE CO.
CONEJOS
LINE
CANAL
9
ALAMOSA FARM
10
Alamosa
SETTLER
Cr.
EXCELSIOR FARM LAT.
COUNTY LINE
VALDEZ
Rio
UNION
35
MILLER
La Jara
Conejos
34
FARM
DENVER & RIO GRANDE
CONEJOS
COSTILLA
BERKSHIRE
33
ANCON
CONEJOS
Rio
Antonio
32

over the line and irrigate lands west and south of Alamosa. The amount of water in most of the creeks is large, and when properly used is probably ample for lands now cultivated. Under the various ditches and canals there are, however, large tracts which, if fully irrigated, will require the maximum amount discharged by the creeks. Many of the farmers are of Mexican descent, cultivating their land according to old methods and using the small ditches constructed years ago.

The opinion is commonly expressed by the irrigators that in order to utilize all the land under ditch it will be necessary to store flood waters at suitable places in the mountains or near the foothills. The amount of water claimed by each ditch is in most cases far greater than is usually received, and the aggregate amount of water adjudicated to various claimants is throughout the valley enormously in excess of the quantity discharged by the streams even in times of flood. During the drought of 1889 some of the crops were lost or injured by the fact that one or more of the large canals was deprived of water at a critical time owing to legal complications and decrees. In 1890, however, there appears to have been ample water for all.

The principal ditches of the county, omitting the large canals heading on the Rio Grande, are: on the north side of Alamosa creek, the Settler, Norland, Scandinavian, and on the south side the Valdez, Miller, Union, and others; on the north side of the Conejos, the Northeastern, Mogote, Berkshire Farm, and on the south side Taos Valley, Aucon, and others. The Scandinavian ditch, covering land on the north side of Alamosa creek, is 5 miles long, 14 feet wide, and cost $5,000. It was begun in 1887, used the following year, and finished in 1890. In 1889 about 200 acres were irrigated, the greater part of this being in wheat and the rest in oats and potatoes. The Valdez ditch, on the south side of the creek, heads higher up near the foothills. It is 6 miles long, 12 feet wide, and cost $1,500. Work on this ditch was begun in 1873 and it was used soon afterward. In 1889 about 400 acres were watered, the principal crops being wheat, oats, potatoes, and peas.

The Miller ditch heads on the south side of Alamosa creek about 5 miles below the Valdez. It is 6 miles long, 10 feet wide, and, since an old dry channel was used for about 4 miles, the cost is estimated to have been only about $500. Work was begun in 1885 and completed in the following year. The Union ditch heads about 3 miles below the Miller and not far from the Scandinavian on the opposite side. It follows a course in general parallel with Alamosa creek and at a distance of a mile or more. It is 10 miles long, 10 feet wide, and cost $8,000. It was built in 1876, and in 1889 irrigated about 2,500 acres in wheat, oats, potatoes, barley, and grass.

The Los Pinos ditch may be taken as an example of one of the old works of the country. It heads on the south side of Pinos creek near the state line. It is a little over 3 miles in length and 4 feet in width and was built probably in 1851. It is owned by private parties, who select one of their number to take care of the ditch and divide the water. In 1889, 405 acres in wheat, corn, oats, barley, potatoes, and pease were irrigated. The Mecitos ditch takes water from the north side of Conejos river about 5 miles above the town of Conejos. It is 4 miles long and 6 feet wide. It was built in 1857 and is owned by private parties. The Mogote ditch heads about 2 miles below the Mecitos and continues in a general northerly direction to Lajara creek. It is 17 miles long, 12 feet wide, and cost $10,000. It was begun in 1887 and finished in the following year. It is stated that in this vicinity, as the years go on, less and less water is needed for irrigation, and that some of the lower lands are becoming so saturated as to require drainage.

COSTILLA COUNTY is on the eastern side of San Luis valley and extends from the Culebra range to the Rio Grande, this stream forming the boundary line between this and Conejos county. In the northern end are the San Luis lakes, which in time of floods receive some water from San Luis river and from creeks rising in the Sangre de Christo mountains. The principal streams flowing toward or into the Rio Grande in this county are Trinchera, Culebra, and Costilla creeks, each of these draining a considerable area of mountain land. The valley as a whole falls toward the center with very gentle inclination and also has a decided slope toward the south. The Rio Grande, however, is upon a low ridge, the bed of the stream being higher than lands a mile away on each side. Thus the water of the river can be carried to great distances away from the main stream, as is the case in the northwestern corner of the county.

The soil in San Luis valley varies greatly in quality, requiring very diverse methods of applying water for irrigation. To produce the best results it has been found that each farmer must have long experience with the particular soil and crop, and there can be no such thing as uniformity in quantity of water to be used or time of application. In the vicinity of some of the larger canals the ground has become so saturated with moisture that water can be found at from 3 to 5 feet below the surface or even less where in former times the earth appeared perfectly dry to depths of 50 feet or more. The presence of this water beneath the surface greatly alters the conditions necessary to produce crops. On some fields with apparently a porous soil the largest yield has been obtained by simply allowing water to stand in the ditches around the tracts, but without applying any to the surface. This is commonly known as subirrigation. At the other extreme there are soils composed mainly of stiff, heavy clay, or adobe, where the water does not seem to penetrate more than a few inches. Between these extremes are all varieties of conditions. A common method of watering is to run the water in laterals at a distance of from 100 to 150 feet apart, allowing it to seep each way. As in the case of Conejos county, most of the crop irrigated is for forage purposes.

The area of land brought under canal is very great, to all appearances far greater than can be supplied by the present amount of water available, even though economical methods are practiced to their full extent. There is complaint from the farmers that canal companies have been reckless in selling shares or rights to the use of water to an amount far in excess of that which can be had. There is, as a matter of course, more or less friction between the smaller irrigators and the large canal companies, the latter being denounced as oppressive monopolies, and some of the former characterized as ignorant and wasteful in their use of water. The diversion of water from the Rio Grande, so far as the summer supply is concerned, is almost complete, and, as in August and September, 1890, the stream near Alamosa may be dry. The river in its natural state probably never ceased flowing in summer, although it has been stated by old settlers that it has been nearly dry twice in 20 years. Most of the larger canals head in Rio Grande county. The Costilla, however, takes water from a point about 8 miles above Alamosa and carries it out easterly and at a distance of about 3 miles from the stream. The total length is about 20 miles, the width 18 feet, and the cost was $10,000. One share in this canal is supposed to furnish 100 inches of water, an amount sufficient for 160 acres.

The condition of irrigation in the eastern part of the county along the Culebra and Costilla rivers is perhaps best given by the following facts, obtained from Mr. E. C. Van Diest, civil engineer. He states that the amount of water carried by the Culebra river varies from 125 to 150 second-feet at its lowest stage, from about July 20 to October 25. From this as a minimum it reaches a quantity of from 850 to 900 second-feet at its highest point, usually about June 25. Costilla river fluctuates at the same times, varying from 60 to 70 second-feet at its lowest stages up to from 800 to 900 second-feet as a maximum.

These 2 streams furnish water for 45 ditches, the larger carrying from 6 to 40 second-feet. These supply a large number of irrigators, mostly Mexican, each cultivating on an average about 15 acres. The water is diverted in nearly all cases by means of wing dams constructed of brush, rock, and logs, only a few ditches having head gates. These dams are usually washed away by each flood and must be renewed or repaired each year. No estimate of the cost of these ditches can be given, as all have been constructed by farmers whose land is supplied. The owners of each ditch elect yearly one of their own body to act as major-domo, whose duty it is to direct the work of cleaning and repairing the ditches and to apportion water in times of scarcity. The annual repairs are often heavy, as the ditches have been constructed in the most primitive fashion with little regard to grade or character of soil, the slope of the ditch being in places so excessive that channels upward of 10 feet in depth have been washed out. From 1 to 4 days' work is generally required annually from each irrigator.

Water is taken by the Mexican owners from the ditches to the small laterals by simply cutting the bank, measuring boxes being exceptional. In times of abundance each person takes as much as he wishes whenever he desires, using often an excess. In times of scarcity, however, the major-domo decides which of the consumers shall be supplied each day, basing his judgment on the appearance of the crops. All irrigating is done by flooding a small area inclosed by checks or borders, keeping the water at a depth of from 2 to 3 inches or more and then allowing it to escape to the next small square or rectangle. Owing to the peculiar methods of subdividing the land among the families of the Mexicans, much of it is held in narrow strips having a length of a mile or more, one ditch or sometimes two crossing each holding. There is often great negligence and carelessness in the control of these ditches and a great part of the water is wasted, so that the water duty appears to be excessively low, 1 second-foot being applied to about 50 acres during the months of May and June and to from 65 to 70 acres in July and August.

CUSTER COUNTY includes a portion of the eastern slopes of the Sangre de Christo range and the higher peaks of Wet mountains. Between these lies the broad area known as Wet Mountain valley, the altitude of which is about 8,000 feet. Streams flow into this from nearly all sides and the water escapes toward the north into Arkansas river through either Texas or Grape creek. On the eastern side of the Wet mountains are the head waters of St. Charles river, which flows through Pueblo county. On these high lands farming is sometimes carried on without irrigation, for there is often sufficient rainfall. Occasionally the season is too dry for crops, and the losses are heavy. The greater part of the area irrigated in the census year was for meadow or hay. As in the adjoining county, mining and stock raising are the principal industries, and there is thus a home market for all produce. With proper irrigation and cultivation a great variety of crops succeed in spite of the high altitude. The water supply is well distributed, coming, as it does, from so many small streams. Each farmer usually has his own ditch, which has been dug with no regard to system and with little reference to the needs of his neighbors. The amount of water available has been quite completely utilized, and during July and August there is usually a deficiency. There are many localities favorable for saving water, notably in the Sangre de Christo range, where there are reported to be a number of small lakes.

DELTA COUNTY is on both sides of the Gunnison river above its junction with the Grand. The Uncompahgre river flows into the county from the south and the north fork of the Gunnison comes in from the mountains on the east. These, with the main stream and numerous creeks, furnish a large amount of water for irrigation. The broad valley of the Uncompahgre extends northerly on both sides of the river, and, uniting with that of the Gunnison, continues down that river, this open land extending into Mesa county. Agriculture is carried on not only in this valley but also in its prolongation northeasterly from the town of Delta along the creeks flowing from the Grand mesa. The altitude of Delta is under 5,000 feet, and as a consequence the climate is mild and favorable to fruit culture.

The water supply of the county is so large and well distributed that irrigation has developed rapidly, and all of the more easily available sources of supply have been long since utilized. The Gunnison river itself, flowing for so much of its course through canyons, is employed with great difficulty, and as a consequence has been of relatively small value in irrigation development. The expense of taking water out of this river is so heavy that irrigators have endeavored to supply their needs by storing the flood waters of creeks. It is possible in this way to gradually increase the area of land cultivated by the expenditure of moderate sums from time to time, although if funds were now available the construction of a large canal from the Gunnison would in the end prove most economical and serviceable. Those persons having prior rights to the use of water are successful in raising crops each year, but the large number of persons not having these suffer to a greater or less extent from scarcity of supply during the critical season.

The creeks flowing south from the Grand mesa have near their head-waters lakes or depressions which can be readily converted into reservoirs by the construction of low dams. A number of farmers whose water supply is deficient have begun the construction of small storage systems, in one case at least $12,000 having been spent. There have not been along these creeks any serious failures, as the farmers have learned by experience to regulate the area of crop planted by the amount of snow on the high lands. If the depth is small the water supply will probably be deficient and the area planted is correspondingly less than it would be otherwise. One group of farmers on Surface creek depend upon the water of that stream until about June 20 or July 1, and when the supply fails take water from a reservoir on the head of Forked Tongue creek, carrying it by ditch over to Surface creek and taking it out a second time to their ditch. The Park reservoir, built at the head of Surface creek, is formed by a dam 150 feet in length and 60 feet wide at bottom, built of timber, earth, and rock. The capacity of this reservoir is stated to be 2,300 acre-feet, and the cost of the dam is estimated to have been $4,000. In many places economy could be enforced if small ditches could be consolidated into one canal, but unfortunately priorities of rights interfere. A man having a prior right on a certain ditch often fears that by any change or consolidation he may lose some advantage, and so jealously guarded are these rights that it is almost impossible to persuade a farmer to make any concession for the public good.

The irrigating ditches in the county are not large, that of greatest extent being probably the canal extending from Montrose county down the valley. The Alfalfa ditch takes water from Surface creek at a point about 14 miles northeast of the town of Delta. It is 9 miles long, 10 feet wide, and cost about $4,000. It was begun in 1880 and used in the following year. In 1889 about 700 acres were irrigated, over one-half of this being in alfalfa and the balance mostly in wheat and oats. The Minnesota canal takes water out of the creek of that name, the head of the ditch being about 3 miles above Paonia. It is 7 miles long, about 5 feet wide, and covers land south of the creek. The North Fork Farmers' ditch takes water from the north fork of Gunnison river about 4 miles above its junction with Minnesota creek. It is 12 miles long, 5 feet wide, and the cost of both of these ditches is estimated to have been $26,000. Both ditches are owned by irrigators, who divide the water in proportion to the ownership. The supply of water in the north fork is large, but in Minnesota creek is sometimes small.

The Ironstone ditch takes water from the south side of Uncompahgre river at a point 9 miles northwest of Montrose. It covers land on the southwesterly side of the river, the total length of the ditch being 14 miles and average width 14 feet. The total cost is estimated to have been $25,000. The canal was begun in 1884 and finished in 1888. Water is diverted by a permanent brush and stone dam and is divided among the shareholders proportionally. The principal crops irrigated are wheat, oats, and barley. The amount of water in the river is insufficient for the needs of the ditch, owing to the fact that other canals have priority of right. The Relief ditch takes water from the Gunnison river about 11 miles above Delta, covering land on the south side of the stream. It is 7 miles long, 8 feet wide, and cost $15,000. It was begun in 1887 and completed in 1891. The ownership is divided into shares, the value of each being about $15, entitling the holder to a certain proportion of the amount of water in the ditch.

DOLORES COUNTY comprises a relatively small portion of the mountain and plateau area near the southwestern corner of the state. By its position beyond the high mountain ranges and the lack of railroad communication it is comparatively isolated. Mining is carried on to some extent in the vicinity of Rico, in the eastern end, and there is fairly good grazing in many localities on the plateaus and hillsides. Agriculture has made but little progress, as the area of fertile land upon which water can be easily diverted is limited. The water supply as a whole is large, but the small creeks first utilized for irrigation sometimes become dry in July or August. Water has been diverted from Disappointment creek, one of the tributaries of Dolores river, and utilized upon land in the vicinity of the little settlement of Lavender.

DOUGLAS COUNTY is near the center of the state, south of Denver and east of the South Platte river, which forms its western boundary. The river in this part of its course flows through canyons and narrow valleys, the western half of the county thus being rough and mountainous, while the eastern part partakes more of the character of the plain region. The area as a whole falls toward the north from the summit of the divide between the Arkansas and Platte rivers. The waters of the South Platte, the principal stream in or near the county, can not be used within this area to any considerable extent, but are taken out by canals running toward the north into Arapahoe county. The tributaries of the river, Plum and Cherry creeks, are utilized as far as possible for irrigation. Besides the cereals, large quantities of potatoes were produced, most of these without irrigation. In this county, especially on the high lands toward the south, the rainfall is relatively large and many crops are raised without the artificial application of water. Probably one-half of the cereals are cultivated without irrigation, the returns obtained being sufficiently large to be profitable. Wherever possible ditches have been taken out from the creeks and springs and water used as far as the supply will go. The creeks are very irregular in behavior, becoming very low or almost dry during the summer, at which time, especially in July and August, they are subject to sudden floods. On this divide heavy rain storms or "cloud-bursts" occur frequently and an enormous volume of water is discharged at such times into one or more of the drainage channels. In Cherry creek the water generally fails by the 15th of June, and as a consequence the farmers must irrigate very early in the season.

There are in this county two notable systems of irrigation. The first of these is what is known as the English Highline canal, owned by the Northern Colorado Irrigating Company, and briefly described in remarks on Arapahoe county. Although the head works and upper 15 miles of canal are in this county the waters are used to but a small extent, being carried to points farther north.

The other large enterprise in the county consists of the storage reservoir upon Cherry creek built by the Denver Water Storage Company for the purpose of supplying water to a canal and smaller storage reservoir at points nearer Denver. This large reservoir is formed by what is known as the Castlewood dam, built at a point where Cherry creek flows through a canyon about 30 miles southeasterly from Denver. (a) The dam is of masonry, is 586 feet in length, and its greatest height is over 63 feet. The capacity of the reservoir has been estimated to be 5,300 acre-feet. The canal, heading at the diverting dam on Cherry creek about a mile below the dam, has been built along the west side of the valley in order to carry water to fruit lands in the suburbs of Denver, the length being about 30 miles. The total cost of the system is stated to have been over $500,000. Other small reservoirs have been built, mainly by private parties, but some of these have been washed out by the heavy rains or cloud-bursts of July and August.

Most of the ditches of this country are short, being from 1 to 2 miles in length, and irrigating alfalfa or other hay crops on cattle ranches. The creeks, as before stated, are very uncertain as regards water supply. There is always a small amount coming from springs, increased by the melting of snow in early spring and by rain from thunderstorms during July and August, but in May and June, when water is most needed, there is usually little to be had. The average discharge of Cherry creek, for example, is estimated to be less than 10 second-feet.

EAGLE COUNTY includes the greater part of the drainage basin of Eagle river, a tributary of Grand river. Irrigation is practiced on the ranches along the valley of this river mainly in the vicinity of Gypsum, Castle, Edwards, and other settlements. The altitude of these lands ranges from about 6,300 up to 8,000 feet. The water supply is large, Eagle river at all times carrying a quantity far greater than can be used upon the cultivated land. The valley is narrow and the fall of the river sufficiently great to enable diversions to be cheaply made, especially upon the hay lands. At places the soil contains a large amount of mineral matter known by the farmers as gypsum, which dissolves rapidly when water is brought in contact with it. When first irrigated the ground often settles, and ditches when built in this soil are for one or two years continually breaking. The solution of the earthy salts causes the sides of the ditches in places to wash out and crops have been lost before the numerous holes could be repaired. In many seasons the amount of water required by the crops is small. Most of the fields received only one or two irrigations, potatoes generally having one wetting, while oats and hay, the principal products, have two wettings.

ELBERT COUNTY is for the most part upon the northward slope of the divide which, projecting out into the Great Plains, separates the head waters of the Platte and Arkansas. On the higher grounds there is no available water supply, but along some of the creeks which flow northerly across Arapahoe county there are irrigating ditches. The earlier settlers have taken up nearly all the water to be had, and those who can not obtain water rights are forced to content themselves with dry farming. Over three-fourths of the crops are raised in that manner, corn, rye, and potatoes being usually a success, though the first two are cut for fodder before maturity. The rainfall is relatively large and even under irrigating ditches the first cutting of alfalfa is usually obtained without the artificial application of water. Attempts have been made to secure water for irrigation by sinking pipes or boxes into and through the sandy channels of the creeks. Considerable money has been spent by the farmers, but with little success, as the amount of water percolating through these sands is very small, and whenever a flood occurs the whole arrangement is liable to be washed out. The ditches of the county are very short, from 1 to 2 miles in length, and derive their water from Running, Bijou, Kiowa, Comanche, and other creeks.

---

[a] The reservoir and distributing system have been described by H. M. Wilson in the transactions of the American Society of Civil Engineers, volume 15, pages 210 to 212.

El Paso county is south of Elbert and includes within its western end Pikes Peak and adjacent portions of the Front range. From the mountains it extends easterly along the southerly slope of the central divide between the Platte and Arkansas rivers. In the western or mountainous end of the county, where the water supply is relatively large, irrigation is carried on, but out toward the Great Plains sheep and cattle raising is the only occupation possible. In the higher valleys among the mountains crops are raised without irrigation, such, for example, as potatoes, oats, corn, rye, and wheat. One farmer states that he obtained $40 per acre for his potato crop, to which water had not been applied. Out on the higher parts of the divide the cereals and potatoes and other vegetables are cultivated in the ordinary manner, as there is no source of water supply, and it is claimed that, as in some of the northern counties of Utah, by careful cultivation fair profits can be made, for the farmer does not incur the expense of the purchase and application of the water. The yield per acre is less than in the case of well irrigated land, but, on the other hand, the cost per acre of production is greatly reduced.

The only stream of importance in the county is Fountain creek, sometimes known as Fontaine qui Bouille, and its tributaries. Its head waters rise on the slopes of Pikes Peak and the range toward the north and flowing easterly unite to form Monument creek. This and Fountain creek, into which it empties, have a general southerly course along the foothills. Near the southern part of the county the creek becomes nearly dry in June and July, its waters being diverted by innumerable small ditches. Nearly all the irrigators suffer for want of water during the height of the season, and there is general demand for systems of storage. Attempts have been made to increase the amount of water available by means of wells, but the water in them is often from 100 to 200 feet below the surface, and the quantity which can be pumped by ordinary windmills is small. In a few instances excavations have been made into the porous beds of sand in valley bottoms and water raised from these by steam vacuum pumps, the required height being but a few feet. At Franceville a deep boring has been made in the hope of obtaining artesian water, and it is stated that a depth of 1,200 feet has been reached, but without success.

Irrigation in the county is carried on mainly by means of small ditches, taking nearly the entire amount available from each mountain stream. Among the larger of these may be mentioned the Lincoln ditch, taking water from the west side of Fountain creek about 2 miles above Little Buttes station. It is 3 miles long, 5 feet wide on bottom, and cost $1,000. It was built in 1864. Water is diverted by a tight brush dam, replaced after each freshet. It is owned by a farmer, who irrigated in 1889 about 235 acres, the greater part of this being in hay. The Lock ditch takes water from Fountain creek near the town of the same name, irrigating land on the east side. The ditch is 3 miles long, 3 feet wide, and cost about $1,000. It was built in 1862 and is owned by private parties, who irrigate about 350 acres, the greater part of this being in blue-stem hay.

Fremont county is southeast of the center of the state and includes land along the Arkansas river below Chaffee county. A number of creeks flow into the river from both sides, those from the north being larger than those from the south, since these latter come as a rule from less elevated regions. In the western part of the county the Arkansas flows through narrow canyons where agriculture is impossible, but toward the eastern end the rocky walls suddenly open out into a comparatively wide valley. At this point the town of Canyon has been built. From here down to Pueblo the valley lands, lying in a narrow strip on each side of the river, have been brought under cultivation by irrigation, and large crops are produced each year. The climate is favorable for fruit culture, and the yield from some of the orchards has been very great.

Water for the irrigation of this part of the Arkansas valley is taken not only from the river but also from the creeks entering on both sides. Most of the ditches are small, having been built by the early settlers so as to cover the ground at little expense, no regard being paid to economy in the use of water or to systematic development of the country. As a consequence low lying lands along the river are in many cases irrigated by water from side creeks, although these could be covered by a canal from the main stream. Thus the higher lands which could be reached by the waters of the creek, but not by the river, are left dry and unproductive.

Many of the farmers state that it will be necessary to resort to water storage in order to cultivate all of the land now under ditch. There is, as in all the adjoining counties, an ample supply of water in the spring, but by the first of July nearly all crops dependent upon creek water begin to suffer on account of its scarcity. There are as usual many complaints regarding the injustice of the distribution of water to prior claimants, and hopes are expressed that legislation regarding water rights will be improved and simplified. As a rule if land is well watered once in May or June it will produce a cutting of alfalfa or a crop of wheat or corn if the ground has been well tilled. The yield per acre under these circumstances is light, but still may be profitable. The creeks of most importance in irrigation are, on the north side, Oil, Four Mile, and Beaver, and on the south side Oak and Hardscrabble. Those on the north side drain mountain slopes south and westward from Pikes Peak, and thus carry a relatively large amount of water throughout the year. Few if any attempts are made to raise crops without irrigation even in the higher parts of the county. Where water is plentiful from three to four crops of alfalfa are obtained.

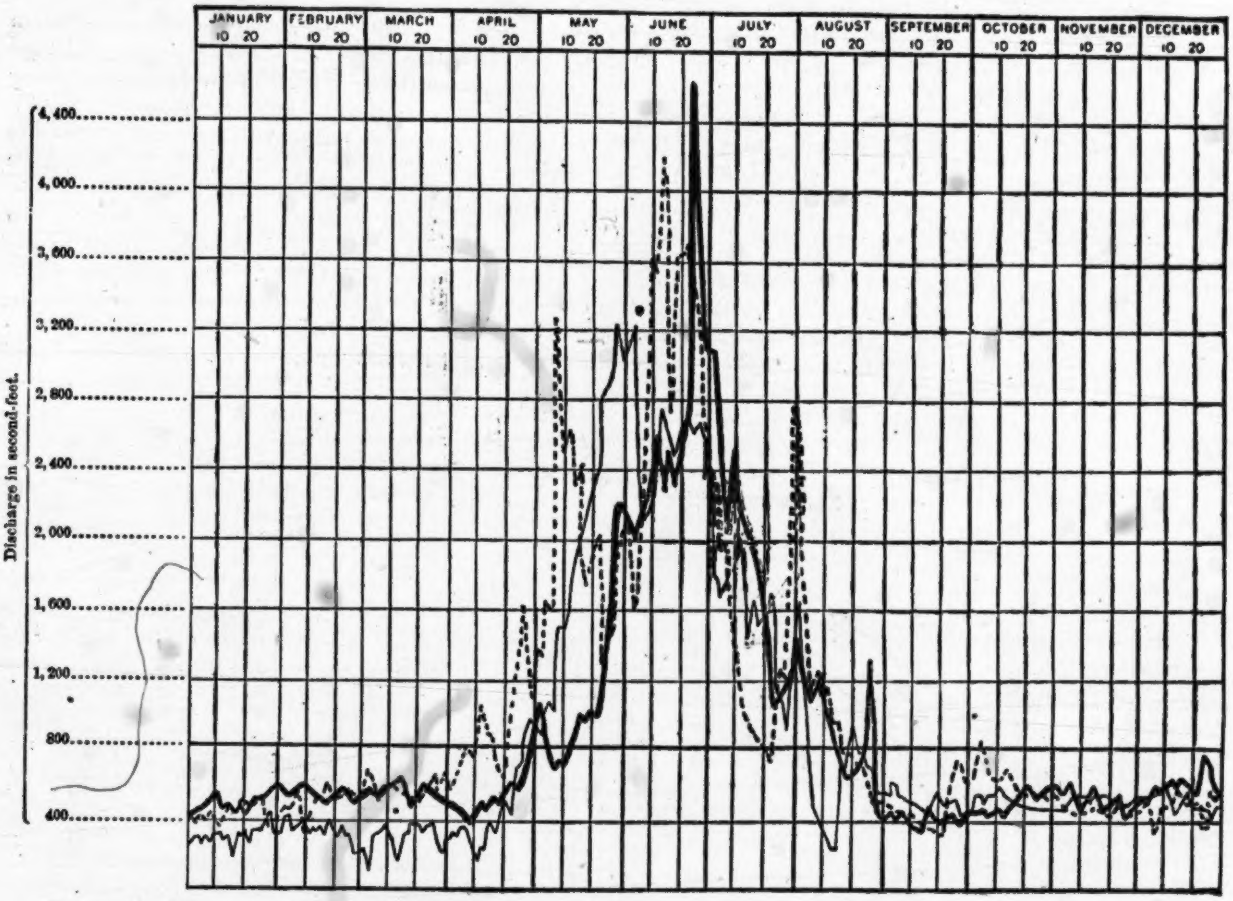
The largest canal system in the county is being constructed by the state, making use of convict labor. The canal heads in the canyon above town and the course as projected follows along the north side of the river, gradually getting away from it and covering more and more land. After passing into Pueblo county it skirts the edge of the foothills and winds its way northerly up the valley of Fountain creek. Near the head the canal passes through tunnels in the mountain spurs and a large amount of stonework has been done, everything being constructed in a substantial fashion under the direction of the state officials. Nearly all the ditches in use are short, from 1 to 3 miles in length, and have been constructed by a few irrigators acting in partnership.

The best series of measurements of the amount of water in the Arkansas have been made at Canyon, a gauging station having been established there by the state engineer in the spring of 1888. In 1889 the work was continued by the United States Geological Survey. (*a*)

---

a The following diagram gives in graphic form the fluctuations day by day for the years 1890 and 1891. The horizontal space, as shown by the headings, represents duration of time, while the vertical distance gives the quantity of water in cubic feet per second. The thin, continuous line represents the quantity during 1890, the dotted line during 1891, and the heavy, full line during 1892. Thus the diagram gives at a glance the changes from day to day and the relative quantities in the various years.

DIAGRAM OF DAILY DISCHARGE OF ARKANSAS RIVER AT CANYON, FREMONT COUNTY, COLORADO.



The following are the gaugings for a series of years:

DISCHARGE OF ARKANSAS RIVER AT CANYON CITY, COLORADO.

(Drainage area, 3,060 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1888.						
January	....	....	400	24,600	0.15	0.13
February	....	....	500	27,750	0.17	0.16
March	....	....	600	36,900	0.22	0.20
April	....	....	1,000	59,500	0.36	0.33
May	1,570	1,280	1,440	88,560	0.54	0.47
June	2,760	1,120	2,090	124,355	0.76	0.68
July	1,870	850	1,350	83,025	0.51	0.44
1888.						
August	1,100	800	932	57,318	0.35	[illegible]
September	850	430	605	35,997	0.22	0.20
October	....	....	500	30,750	0.19	0.16
November	....	....	500	29,750	0.18	0.16
December	....	....	400	24,600	0.15	0.13
Per annum	2,760	400	860	623,105	3.60	0.28

Garfield county includes a comparatively narrow strip of land on the western side of Colorado, mainly within the drainage basin of Grand river. The principal part of the agriculture, as well as the population, is in the valley along this river, extending from Carbondale and Glenwood Springs down beyond Parachute. The earlier settlers built small ditches leading from creeks and streams, draining the mesas on each side of the valley, the difficulties of taking water from Grand river itself being too great for their scanty means. The waters from these small streams have been overappropriated, and there is a deficiency of supply except in time of flood. Wherever sufficiently irrigated good crops are produced, and fruit is of high grade, the climate being well adapted to fruit culture. Grand river carries at all times of the year a large amount of water, and by the construction of suitable canals much of the valley could be brought under irrigation. The mesas, which bound the valley and form the greater part of the county, are too high to be irrigated, and, although having a good soil, are of little value except for cattle raising. Within Grand valley cattle find fair grazing, not only on the lower lands but up to heights of 1,000 feet or more above the river.

Most of the water rights in the county have been adjudicated, but there is more or less dissatisfaction expressed, especially by those whose supply is less than their requirements. Probably at least 25 per cent of the crops are lost in ordinary years on account of the insufficiency of water supply and difficulty of properly distributing it. Although in this county there is as a whole a large quantity of water, yet the greater part can not be utilized by the present ditches, since it is in the Grand river, too far below the general level. The small amount in the side streams being insufficient for the needs of the irrigators there are innumerable conflicts, which can only be settled, if at all, by greater economy on the part of individuals and by systems of storing flood water.

The following descriptions of a few of the larger ditches will serve to give the general character. The Rockford ditch heads about 4 miles above Satank, carrying water out on the east side of Rock creek, one of the tributaries of Roaring Fork river. It is 4 miles long, 4 feet wide, and cost about $2,000. The canal was begun and used in 1883. It is owned by private parties, who in 1889 irrigated about 150 acres, most of this being in hay, oats, and other grain, with some vegetables and fruit. The water supply in this valley, being near the head waters, is generally abundant and large crops are raised when properly irrigated.

DISCHARGE OF ARKANSAS RIVER AT CANYON CITY, COLORADO—Continued.

Months.	Discharge in second-feet.			Total for month in acre-feet.	Run-off.		Months.	Discharge in second-feet.			Total for month in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.		Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.							1891.						
January	....	....	300	18,450	0.11	0.10	January	505	325	431	26,506	0.16	0.14
February	....	....	300	16,620	0.10	0.10	February	580	365	474	26,307	0.16	0.15
March	....	....	300	18,450	0.11	0.10	March	685	530	586	36,039	0.22	0.19
April 17 to 30	438	214	300	17,850	0.11	0.10	April	1,600	560	857	50,992	0.31	0.28
May	1,960	324	600	36,900	0.23	0.20	May	3,700	1,340	2,012	123,738	0.76	0.66
June	2,010	1,002	1,374	81,753	0.50	0.45	June	4,230	1,600	3,291	195,814	1.20	1.07
July	1,150	290	602	37,023	0.23	0.20	July	2,810	770	1,468	90,282	0.55	0.48
August	2,620	243	340	20,910	0.13	0.11	August	1,925	530	951	58,486	0.36	0.31
September	258	190	220	13,090	0.08	0.07	September	715	345	473	28,143	0.17	0.15
October	284	190	223	13,715	0.08	0.07	October	825	530	624	38,376	0.24	0.20
November	335	243	299	17,790	0.11	0.10	November	530	430	498	29,631	0.18	0.16
December	438	274	335	20,602	0.13	0.11	December	605	345	476	29,274	0.18	0.16
Per annum	2,620	190	433	313,153	1.92	0.14	Per annum	4,230	325	1,012	733,588	4.49	0.35
1890.							1892.						
January	494	180	310	19,065	0.12	0.10	January	630	345	496	30,504	0.19	0.16
February	446	250	363	20,146	0.12	0.12	February	555	430	493	28,347	0.17	0.16
March	391	180	320	19,683	0.12	0.10	March	605	430	524	32,226	0.20	0.17
April	980	200	477	28,381	0.17	0.16	April	715	410	522	31,059	0.19	0.17
May	3,270	841	2,090	128,535	0.79	0.68	May	2,250	685	1,241	76,322	0.47	0.41
June	3,200	2,068	2,611	155,354	0.95	0.85	June	4,750	1,780	2,787	165,826	1.01	0.91
July	2,132	920	1,571	96,616	0.59	0.51	July	3,050	1,000	1,708	110,577	0.68	0.59
August	1,425	580	670	41,205	0.25	0.22	August	1,425	455	769	47,293	0.29	0.25
September	625	455	519	30,880	0.19	0.17	September	530	365	435	25,882	0.16	0.14
October	605	505	531	32,656	0.20	0.17	October	605	410	511	31,426	0.19	0.17
November	555	480	522	31,059	0.19	0.17	November	605	455	527	31,356	0.19	0.17
December	580	455	502	30,873	0.19	0.16	December	630	480	561	34,502	0.21	0.18
Per annum	3,270	180	874	634,453	3.88	0.28	Per annum	4,750	345	889	645,320	3.95	0.29

The above table gives not only the greatest, least, and average flow of the stream but also shows the total quantity discharged for the whole month and the relation of this to the total area drained. This latter, the run-off, is expressed in two ways. In the next to the last column is given the depth in inches which the quantity which flowed away during the month would have if put on a plane of an area equal to that of the catchment basin. In the last column is the average amount flowing during the month divided by the area of the basin, thus showing the average amount of water furnished per square mile drained.

The Grand river and Roaring Fork canal takes water from Cattle creek, heading at a point 7 miles above Glenwood Springs. It flows on the north side of Cattle creek and on the eastern side of Roaring Fork valley down to Glenwood Springs. It is 7 miles long, 3 feet wide, and cost $12,000. It was begun in 1887 and used in the following year. Water is diverted from the creek by means of a tight dam of logs and dirt, replaced each year. The canal is owned by a corporation, each stockholder being entitled to water in proportion to the stock held. In 1889 only about 90 acres were irrigated, owing to the fact that other irrigating ditches were taking the water. The Roaring Fork is so far below the land to be irrigated that it is not practicable to take out water, and a supply, usually insufficient, must be obtained from the small streams. Owing to the impossibility of securing water from this canal a trial has been made of using a centrifugal force pump driven by water power, the entire plant costing about $3,000.

The Last Chance ditch takes water from Grand river near Ferguson, carrying it out on the south side to and below Rifle. It is over 8 miles long, 4 feet wide, and cost about $8,000. It was begun in 1887, and though not completed was used to a small extent in the census year. Water is diverted by a long cutting, bringing the head sufficiently low to receive water. In 1889 about 75 acres were irrigated, most of this being in forage crops. The water supply is large, ample for the needs of the ditch when completed.

GILPIN COUNTY, the smallest in the state, includes a part of the mining region west of Denver. It is among the high mountains, the valleys being at an elevation of 8,000 feet and upward. There are a few patches of arable land along the streams, but the temperature is so low that forage crops alone are raised, these consisting of grasses and cereals cut before maturity. The ditches within this county have been built for placer mining.

GRAND COUNTY includes the Middle park, situated in the north central part of the state on the head waters of Grand river. This park is partially surrounded by a loop in the continental divide, and although between the North and South park it is on the opposite side of the continental watershed, its streams flowing to the Pacific ocean. The valley lands are at an elevation of about 8,000 feet and the climate is too severe for general agriculture, although with irrigation it is favorable for the production of hay and the hardier vegetables and cereals. Each ranch has its own ditch and sufficient agriculture is practiced to supply common needs. Potatoes are often raised without irrigation, especially near or within the timbered areas, tree growth marking the localities where the supply of moisture is better than usual. As in the other parks the water supply is large, well distributed, and is freely used by the ranchmen. The grass is irrigated almost continuously during the growing season, a great part of this water returning to the stream, thus, apparently, not diminishing the amount below. Besides the native grasses timothy and redtop are grown successfully, but the altitude is regarded as too high for alfalfa. Some of the bottom lands are wet by the annual overflow of Grand river.

GUNNISON COUNTY includes the greater part of the headwaters of Gunnison river above the grand canyon of that stream. It is bounded on the north by the Elk mountains and on the east by the Saguache range, this being a part of the continental divide. As in adjoining counties, mining is the principal industry, and next to this in importance is stock raising, the mountain slopes and hills furnishing excellent grazing. Along the valley of the Gunnison river in the vicinity of Gunnison and up along Ohio creek, Slate river, and Tomichi creek are valley lands containing natural meadows. A great part of this low land has been brought under irrigation by ditches taking water from the streams mentioned. The altitude is about 8,000 feet and agricultural products consist principally of the hardier cereals usually cut for hay, as well as timothy, redtop, and other forage plants. Potatoes are occasionally raised without irrigation, but this may be considered as exceptional. The water supply of the county is abundant at all times of the year, and the area cultivated can be increased without interference with water rights.

HINSDALE COUNTY covers a part of the high mountain region west of the San Luis valley. It includes the upper waters of the Rio Grande, and extending both north and south over the continental divide, takes in a part of the watershed tributary to Lake fork of the Gunnison, and on the south a few of the streams flowing into the San Juan river. There are numerous mines in the county, the moutains containing many deposits of precious minerals. Cattle graze in the high valleys, but there are few places at which agriculture can be successful on account of the great altitude and the short summer. The lowest points in the county are probably considerably over 8,000 feet above sea level. In the vicinity of Lake city and on the Cebolla or White Earth creek a little irrigation has been attempted, mainly for the purpose of raising forage crops, there being plenty of water and but little arable land. Each farmer has his own ditch, and besides hay raises a few of the hardier vegetables.

HUERFANO COUNTY lies along the eastern side of the Sangre de Christo and Culebra ranges, these forming the watershed between the Arkansas and the Rio Grande. The slopes of these mountains are drained by the Huerfano river and its tributaries, which, flowing northeasterly, empties into the Arkansas. Agriculture is carried on mainly along this river in the valleys wherever water can be diverted, the greater number of the farmers being of Mexican descent. In the higher valleys some of the crops are raised without irrigation, mainly on account of the difficulty of obtaining water. The supply as a whole is far below the needs of the land under cultivation, and hopes have been expressed by the majority of the farmers that it will be possible to increase the summer flow of the streams by storage reservoirs.

Jefferson county includes a great part of the plain extending from the foot of the mountains to the city of Denver. This area is crossed by many creeks whose supply of water is large and perennial. As a consequence ditches and canals have been built, covering the comparatively level ground with a network of small water courses and bringing under cultivation nearly all of the arable land within reach. The complexity of these systems is shown on plats prepared by the state engineer of Colorado and on the topographic sheets of the United States Geological Survey. On the western side of the county among the mountains are small areas upon which cereals and vegetables are grown without the artificial application of water, and in the valley lands are places where corn has been raised without irrigation by planting the quick growing varieties and keeping the ground well cultivated. Taking the county as a whole, however, agriculture without irrigation is exceptional.

The water supply of the county comes from the South Platte, which for over 50 miles forms the southeastern boundary, and also from tributaries which, crossing the county, flow into this river. The principal of these in order down stream, namely, from south to north, are the north fork of the South Platte, Deer creek, Bear creek, and Clear creek. The north fork of the South Platte enters through canyons and its waters are used for irrigation only up among the mountains. The waters of the other creeks are diverted immediately after leaving the lower canyons and are carried out on both sides of the stream by canals and ditches, heading in succession at short intervals below each other. The capacity of these systems for distributing water is far greater than the supply usually available, and as the hot weather comes on it is usually necessary to deprive several of the ditches of all or part of the water needed by them in order that persons having prior rights may be supplied. It thus results that the later settlers complain of hardship or even injustice, and the assertion is made that the older settlers receive more water than is justly due them.

The development of irrigation without systematic control has resulted in the construction of many small ditches each so located as to best supply some individual or group of individuals. These have been followed in time by larger canals, in many ways better planned, but whose location and construction have often been modified by the presence of older ditches and water rights. In distributing the water according to priorities of right it necessarily happens that the ditch lowest on the stream and least economical in its use of the water may be entitled to more water than one commanding more land and built to utilize its supply in the best possible manner. It is apparent to the irrigators that the only way of remedying the evils thus arising is by the construction in the mountains of storage reservoirs whose capacity shall be so great as to hold the waters which otherwise run to waste during winter and spring. There are, however, many obstacles arising not only from the difficulty and expense of constructing retaining dams but also in the recovery of the water from the stream in which it must flow and in its distribution. As the matter is at present few of the larger canals can deliver to the irrigators an amount of water sufficient for their demands, and since payment for water is usually made in advance, the farmer may suffer a double loss, namely, in money thus paid and in crops.

Measurements of the amount of water flowing in the South Platte, Bear creek, and Clear creek have been made by the state engineer of Colorado, and the daily discharge during the summer season at least has been computed for a number of years. At the gauging station near Deansbury, in the canyon of the river about 26 miles south of Denver, as stated in the description of Park county, observations were begun in July, 1887. The area of the catchment basin above this point is about 2,600 square miles, the greater portion of this being in the South park. The average discharge from May to October, inclusive, in 1888, was 323 second-feet; in 1889, 297 second-feet, and in 1890, 374 second-feet. Bear creek has been measured at a point 2.5 miles above Morrison, being thus above the heads of all canals, observations being begun in August, 1887. The highest water recorded during the spring and summer months was 195 second-feet, occurring in May, 1889, a flood later in the season, however, being probably of greater quantity. The lowest water of fall and winter was about 15 second-feet. The average discharge of the stream taking the year through is probably not far from 50 second-feet, and the drainage area is approximately 141 square miles. Turkey creek, immediately south of this stream and flowing into it below Morrison, carries probably a less amount of water and has been known to become dry. These streams are included within what is known as water district No. 9.

Clear creek has been gauged at a point in the canyon about 7 miles above Golden, above places where water has been diverted to any notable extent for irrigation purposes. The drainage area above this place is 338 square miles. The average discharge of this stream is probably from 300 to 400 second-feet, falling to 50 second-feet or even lower in time of drought. One flood, as estimated by the state engineer, discharged at the rate of 8,700 second-feet for 2 hours, the river falling immediately to a little over 200 second-feet. The canals and ditches taking water from this creek and its tributary, Ralston creek, are included within water district No. 7. Within the two districts mentioned, Nos. 7 and 9, there are a large number of reservoirs projected or constructed. The object of these is to hold surplus water from the creeks at points convenient to the lands of the irrigators. In this way the problem of distribution of stored waters has been done away with here, since the water is not returned again to the stream, but is drawn back into the canal or to distributaries.

A brief description is herewith given of a few of the many ditches in this county. Arnette ditch takes water from the south side of Bear creek below Morrison and continues in a direction a little south of east out toward the South Platte river. It is 8 miles long, about 10 feet wide, and cost $20,000. It was begun and first used in 1872.

It is owned by a corporation, and water is divided according to the number of shares held by each owner. The principal crop raised is alfalfa, and next in importance are the cereals. The Ward and Kendrick ditch takes water from the opposite side of Bear creek, carrying it in a general northeasterly direction. The total length of the main ditch is 14.5 miles, average width is 6 feet, and the cost of ditches was $16,000, to which should be added $11,000 for the expense of constructing reservoirs. In 1889 about 900 acres were irrigated, the greater part being in alfalfa and cereals. The engineer and part owner of this canal, F. C. Kendrick, estimates that for wheat or oats there are required 0.75 to 0.90 acre-feet and for alfalfa, clover, and timothy from 1.25 to 1.40 acre-feet.

The Golden City and Ralston creek, commonly known as Church ditch, takes water from Clear creek about a mile above Golden, carrying it out on the north side of the stream. The total length is 27 miles, width 12 feet, and the cost was $65,000. It was begun in 1864 and since that time has been enlarged several times. It is owned by a corporation selling water to irrigators, the value of water right being about $20 per acre. On the opposite side of the creek and heading at a point higher up is the Golden ditch, 14 miles in length and from 8 to 10 feet in width. This was begun in 1871, and the cost is stated to have been $85,000. It supplies the town of Golden and in 1889 irrigated about 2,800 acres. Below these ditches are many others, some being longer, but most of them from 1 to 5 miles in length.

KIOWA COUNTY is in the eastern end of Colorado about 12 miles north of the Arkansas river. It is crossed by Adobe and Big Sandy creeks, both of these, however, being dry during the summer. The surface of the county is gently undulating, and there are shallow basins in which water collects after heavy rain, the annual precipitation not being sufficient to erode well defined drainage systems. The county was settled about 1887, and fair crops were raised for 1 or 2 years. There were, however, so many losses from drought in 1889 and 1890 that many of the farmers moved to other parts of the state, and grazing is now the principal occupation.

The Bob Creek canal, owned by the Colorado Land and Water Company, has been extended into the southwestern corner of this county since 1889. Work has been begun also on ditches to take water from Adobe and Big Sandy creeks, reliance being placed upon the water saturating the pervious channels and upon storage reservoirs. It is somewhat doubtful whether irrigation can be satisfactorily practiced on account of the difficulty of obtaining a sufficient supply from the Arkansas for the large canal and carrying it the requisite distance. In the case of the smaller canals also it is questionable whether water can be had at critical times. There are many wells from which water for cattle can be obtained, but the quantity is too small to be of importance in irrigation.

KIT CARSON COUNTY in eastern Colorado, adjoining Kansas, is upon a portion of the central divide of the eastern half of the state, and contains few perennial streams. It is for the most part a nearly level prairie with fertile soil. The principal water supply is from wells sunk to depths of from 100 to 200 feet. The cereals under careful cultivation do fairly well, but the principal occupation is stock raising, cattle feeding both summer and winter on the buffalo grass. Most of the settlers came into the county about 1886 or 1887, and tried to make homes. Their history has been similar to that of the inhabitants of other counties of eastern Colorado and western Kansas. Some have succeeded in adapting themselves to the conditions, while others have failed on account of the prevailing droughts. Irrigation is being attempted in a small way by making use of the springs and small streams at and near the head waters of the tributaries of the Republican river. These trend in a general northeasterly course across the county toward the northwestern corner of Kansas, through which they flow. The streams are dry at times, but near their sources and at a few points below there is usually to be found a small amount of water, which can be diverted for use upon gardens and orchards

LAKE COUNTY includes the head waters of the Arkansas in the vicinity of Leadville, the southern line of the county being a short distance below Twin Lakes. The valley land ranges from 9,000 to 10,000 feet in altitude, and the only crops of importance are for hay. This commands a price of about $20 per ton at Leadville. The ditches, deriving an ample supply from the mountain streams, are small and are owned usually by one or two farmers. Hay is made from native grasses and from timothy. The climate is probably too severe for the success of alfalfa, although vegetables are raised to a small extent. The water supply is large for the needs of the county, but it is in such localities as these that great storage works should be constructed for the purpose of increasing the discharge of the Arkansas during summer. All along the river, especially on its course through the Great Plains, there is each year a demand for water and there are losses of crop on account of the small amount available. During and since the census year great canals have been constructed, one or two of which alone could carry the average amount flowing in the stream during summer. Water rights under these canals have been sold to farmers in spite of the fact that more than the amount usually flowing in the river is claimed by individuals and companies, general reliance being placed upon the hope that reservoirs would be constructed in this and other counties of high altitude.

Measurements of the amount of water available for storage were begun in 1889 and carried on by the Geological Survey until October of that year. The gauging stations were on the east fork of the Arkansas, on Tennessee fork, and Lake fork, all of these being not far from Leadville, and also on Twin Lake creek below the lakes. The average discharges at the first three stations for the greater part of spring and summer were respectively 95, 91, and 116 second-feet. On Twin Lake creek, having a drainage area of 102 square miles, the greatest discharge was 632 second-feet and the least 19 second-feet, the average from April to October being 212 second-feet. Surveys were made for a number of reservoir sites, the most important of these being Twin Lakes. It has been found that water can be conducted to these lakes from a point near Hayden on the Arkansas river, increasing the catchment area tributary to the lakes to 387 square miles. By building a suitable dam across the outlet and deepening the channel between the lakes, the storage capacity could be increased to121, 800 acre-feet. (a)

La Plata county is in the southwestern corner of the state, being south of the San Juan and San Miguel mountains and embracing the catchment area of streams flowing southerly into the San Juan river in New Mexico. The agricultural lands form a relatively small part of the area, being in the valleys along Las Animas, Florida, La Plata and other streams. Their altitude is great, the elevation of Durango, the principal town, being slightly over 6,400 feet. Many of the cereals, including corn, are successfully produced, as well as the ordinary vegetables and the hardier fruits. Nearly all crops are irrigated, although in a few localities dry farming has been attempted. The principal part of the land under irrigation is utilized for the production of hay or for grazing purposes, stock raising being the industry next in importance to mining. The water supply of the county is large, and in most of the valleys there is a greater quantity available than is needed upon the narrow areas of agricultural land. The smaller creeks, as is usually the case, become nearly dry during summer, but the main streams have a large perennial discharge. Many small ditches have been built by the farmers, and there are a few canals owned by corporations, the principal of these being the Animas Valley Ditch Company and the Florida Company.

The Florida Mesa ditch takes water from the west side of Rio Florida and covers land about 5 miles east of Durango. The main ditch is 12 miles long, 8 feet wide, and the cost was $16,000. The company sells perpetual water rights at the rate of $500 per second-foot, this being considered sufficient for from 50 to 100 acres. The annual cost of maintaining these water rights was in 1890 $37.50 per second-foot. In the Animas valley north of Durango are many small ditches covering the valley land, but the bordering mesas near the town have been brought under irrigation to a very small extent, although a number of projects for reaching the higher lands have been suggested. With the throwing open of the Ute Indian reservation and the neighboring military reservation many thousands of acres of good farming land will be brought under cultivation, and the construction and enlargement of irrigation works from the Las Animas and La Plata will be greatly stimulated.

Larimer county is in the center of the northern side of Colorado and adjoins Wyoming. It extends from the continental divide easterly beyond the Front range of the Rocky mountains and includes the head waters of the North Platte and Laramie rivers, flowing northerly into Wyoming, and the drainage basins of the principal streams which flow east to form the South Platte. The water supply in the county is widely distributed and is so situated as to be easily employed for irrigation. In the western end of the county is North park, a broad valley having an altitude of 8,000 feet and over, surrounded by mountains rising to 12,000 or even 13,000 feet. The park is about 20 miles in width and 30 miles in length, and receives from all sides the drainage from lofty peaks. The small streams on each side of the park unite and flow northerly, the North Platte, formed by their union, passing out of the park through narrow canyons, which extend into Wyoming. In the park the principal occupation is grazing, about the only crop raised being hay for winter feed. The precipitation during summer even at this altitude is small and irrigation must be employed. The temperature is too low for most of the ordinary crops, but by the application of water timothy and the native grasses attain a heavy growth.

In North park are many ditches dug by the owners of ranches to bring out water for the purpose of raising winter feed, but there are few, if any, incorporated companies. The park is included in water districts Nos. 46 and 47. In the first of these, including the western part of the park, the fifth biennial report of the state engineer enumerates 88 ditches, and in No. 47, which lies on the east side of the park, there is given a list of 159 ditches. In some instances, however, the same ditch is entered twice in these lists. The water supply usually has been ample for all demands and there has been little necessity of interference or regulation by state officials.

The Big Laramie river rises in the Medicine Bow mountains east of North park and flows northerly through narrow valleys into Albany county, Wyoming, where after leaving the mountains it turns toward the east and flows out upon the Laramie plains. Its waters are used to a very small extent, if at all, in Colorado, but there are localities in which the water could be held by storage if so desired by the users upon the plains below.

In the eastern half of the county the streams flow directly out toward the plains, receiving the drainage from the Front range and its northern prolongation, the Laramie hills. A large amount of water comes from this hilly or mountainous region and creeks of great importance in irrigation are formed. The most northerly of these is the Cache la Poudre; south of this in order are the Big Thompson, Little Thompson, St. Vrain, and others in Boulder county, south of Larimer. From the point where these creeks leave the mountains a large number of canals and ditches have been taken, heading in succession on both sides of the creeks and extending out upon the plains. The drainage basin of each of these creeks has been made, according to Colorado law, into a separate water district. The catchment area of the Cache la Poudre is known as district No. 3, and includes the northeastern portion of Larimer county and a part of the western end of Weld county. Big and Little Thompson creeks form district No. 4, thus including the southeastern corner of Larimer county and parts of Boulder and Weld counties.

---

[a] See engineering results of the irrigation survey. Thirteenth Annual Report of the United States Geological Survey, 1892.

Irrigation has reached a very high state of development in the eastern end of Larimer county, and the water supply has been utilized to such an extent that increase of crop area must come mainly by the storage of flood waters. The comparatively large and easily available supply of water made possible the construction by the early settlers of a great number of small ditches. These in time have been succeeded by well-built canals, and the water of the streams has been appropriated so completely that during the summer time, and even in late spring, it becomes a matter of difficulty and expense to apportion the amount available to the legal claimants. To guard against loss a few of the irrigators have constructed reservoirs, which are filled during times of high water, and when the ditches are closed this water is utilized. Many of the farmers state that it will be necessary not only to store water in suitable depressions among the foothills but also to build reservoirs in the mountains, taking advantage of every possible means of regulating the water supply.

Many of the smaller streams become almost if not quite dry at times. Along these streams in the hilly or mountainous part of their course farming is carried on only to a small extent, the principal crop, as in the case of the North park, being winter feed for range cattle. It is only farther down stream, where the elevation is about 5,000 feet or under, that a greater variety of crops is raised. Here, where water has its greatest value, the ordinary supply has long been recognized as being deficient, and there is complaint from the farmers that in spite of this fact irrigation companies are building and extending canals and selling water rights. Some of these companies, however, are providing reservoirs, and in one case at least, where a canal was cut off, it is claimed that the entire crop was saved during 1889 by stored waters.

The daily discharge of Cache la Poudre creek has been computed during the summer months at least since 1884, the figures being based upon gaugings made by the state engineer of Colorado and by Professor L. G. Carpenter, of Fort Collins. The station at which observations are taken is situated about one-half mile above the mouth of the canyon, 12 miles above Fort Collins. Striking features are the relatively large discharge during 1884, 1885, and 1886 and the decreased amount during the succeeding years. (*a*)

---

a The following are the gaugings for a series of years:

DISCHARGE OF CACHE LA POUDRE CREEK, ABOVE FORT COLLINS, COLORADO.

(Drainage area, 1,060 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1884.						
March 15 to 31	92	48	67	4,120	0.07	0.06
April	707	64	219	13,030	0.23	0.21
May	5,393	453	2,537	156,025	2.77	2.39
June	5,611	3,474	4,812	286,314	5.08	4.54
July	3,970	862	2,144	131,856	2.34	2.03
August	1,231	423	792	48,708	0.87	0.75
September	446	230	305	18,147	0.32	0.29
October 1 to 10	224	196	205	12,607	0.22	0.19
1885.						
April 4 to 30	822	241	447	26,596	0.47	0.42
May	1,965	954	1,419	87,268	1.55	1.35
June	3,857	2,235	2,910	173,145	3.07	2.74
July	3,186	1,076	1,857	114,205	2.02	1.75
August	1,116	369	656	40,344	0.71	0.62
September	387	210	273	16,243	0.29	0.25
October 1 to 10	210	202	203	12,484	0.22	0.19
1886.						
April 27 to 30	447	369	405	24,097	0.43	0.38
May	2,660	404	1,309	80,403	1.42	1.23
June	2,584	1,227	1,875	111,562	1.97	1.77
July	1,175	392	717	44,095	0.78	0.68
August	1,476	232	338	20,787	0.37	0.32
September	284	115	185	11,007	0.19	0.17
October	140	120	129	7,933	0.14	0.12
1887.						
May 18 to 29	2,380	1,150	1,822	112,053	1.98	1.72
June 14 to 30	1,970	1,050	1,401	83,360	1.47	1.32
July	1,260	410	735	45,202	0.80	0.69
August	430	220	307	18,880	0.33	0.29
September	300	110	175	10,412	0.18	0.16
1888.						
April	350	100	181	10,770	0.19	0.17
May	790	250	483	29,704	0.52	0.45
June	1,490	680	1,113	66,223	1.17	1.05
July	690	260	420	25,830	0.46	0.40
August	500	140	213	13,100	0.23	0.20
September	180	70	109	6,485	0.11	0.10
1889.						
January	342	71	151	9,286	0.16	0.14
February	198	69	106	5,883	0.10	0.10
March	125	41	46	2,830	0.05	0.04
April	342	48	113	6,723	0.12	0.11
May	1,886	215	649	39,913	0.71	0.61
June	1,960	837	1,338	79,611	1.41	1.26
July	844	271	514	31,611	0.56	0.48
August	455	67	187	11,500	0.20	0.18
September	75	56	67	3,986	0.07	0.06
October	92	55	69	4,243	0.08	0.06
November	122	46	88	5,236	0.09	0.08
December	89	33	64	3,935	0.07	0.06
Per annum	1,960	33	283	204,757	3.62	0.26
1890.						
January	101	46	82	5,043	0.09	0.08
February	138	37	79	4,384	0.08	0.08
March	126	47	85	5,227	0.09	0.08
April	481	71	200	11,900	0.21	0.19
May	1,710	436	1,044	64,206	1.13	0.99
June	1,804	1,016	1,280	76,158	1.35	1.21
July	1,025	336	649	39,950	0.71	0.61

The principal towns are along the eastern edge of the county near the foothills. In the vicinity of each of these the systems of ditches are exceedingly complicated, a number coming out on both sides of the stream and following in the same general direction in tortuous courses according to the slope of the land. In the vicinity of Fort Collins and Loveland irrigation has been most completely developed. The lower lands are well watered by the many ditches, and in some places the ground has been so completely saturated that it is not necessary to irrigate, sufficient moisture coming from seepage. The higher grounds are in many places considered best for agriculture, but unfortunately it is not possible at all times to secure water for these. Since the county lines and the water districts, based on natural divisions, do not coincide, a direct comparison can not be made between the figures contained in the report of the state engineer of Colorado and the results obtained by the census. The water commissioners report that in 1890, in district No. 3, on the Cache la Poudre, 139,222 acres were irrigated by ditches and 10,825 acres by stored water; and in district No. 4, Big Thompson, 89,790 acres were irrigated by ditches and about 12,000 acres by water from reservoirs. No distinction, however, was made in their estimates between lands imperfectly irrigated and those upon which crops were successfully raised.

The relative location of the principal canals and irrigating ditches of this county is shown upon a map of portions of water districts Nos. 3 and 4 accompanying the fourth biennial report of the state engineer. Illustrations of this character show the complications due to the topography of the country and to the large number of ditches taking water from the same stream and carrying it out in the same general direction. These in many instances cross each other, and at first glance seem to be involved in hopeless confusion. Many of the longer canals run nearly parallel for many miles, each one losing more or less water by evaporation and seepage.

Among the principal canals in the drainage basin of Cache la Poudre creek may be mentioned the North Poudre, taking water from the north fork, and below the junction of the north and south forks the Highline, Dry Creek, Cache la Poudre, Larimer and Weld canal, Pioneer ditch, Lake canal, and Cache la Poudre canal. All of these are on the north side of the creek, and the latter is almost entirely within Weld county. On the south side of the stream the canals are shorter, since of necessity they run along the foothills toward Big Thompson creek and do not extend out upon the plains. The principal of these are the Pleasant Valley and Lake canal, the Fort Collins canal, the Larimer County canal No. 2, and Boxelder ditch. The North Poudre canal is about the only large canal lying wholly in Larimer county, the others extending out into Weld county. Its length is 20 miles, average width 14 feet, and the cost was $300,000. It was begun in 1881 and completed in 1884. It is owned by a corporation which sells water rights, the value of these being, it is stated, about $15 per acre. The ditch is rapidly being improved and more land brought under cultivation. The accompanying illustration shows the character of the diversion line and some of the difficulties overcome in construction. The view is of the upper end of the 627-foot tunnel, being about 3,000 feet below the head gate and dam.

In district No. 4, including in this county the greater part of the drainage area of Big Thompson creek, the canals are secondary in number and size to those named above. The principal irrigating systems on the north side of Big Thompson creek are the Hamaqua, Louden Irrigating, Loveland and Greeley, and the Farmers Irrigating canals, and on the south side of the creek the Handy, Home Supply, Hillsboro, and the Big Thompson No. 1 ditches. The Louden canal is about 19 miles long, 14 feet wide, and has cost about $50,000. It was begun in 1877 and was finished in 1880. Water is diverted by a wing dam of cobblestone. The canal is owned by a

DISCHARGE OF CACHE LA POUDRE CREEK, ABOVE FORT COLLINS, COLORADO—Continued.

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1890.						
August	404	150	287	17,650	0.31	0.27
September	183	58	103	6,128	0.11	0.10
October	118	55	80	4,920	0.09	0.08
November	89	41	61	3,630	0.07	0.06
December	....	....	70	4,305	0.08	0.07
Per annum	1,804	37	335	243,501	4.32	0.32
1891.						
January	145	44	92	5,658	0.10	0.09
February	131	57	79	4,384	0.08	0.08
March	76	32	59	3,628	0.06	0.06
April	344	39	144	8,568	0.15	0.14
May	2,490	355	1,221	75,092	1.33	1.15
June	5,060	985	1,900	113,050	2.01	1.79
July	1,003	278	541	33,271	0.59	0.51
August	292	155	228	14,022	0.25	0.21
1891.						
September	158	115	138	8,211	0.15	0.13
October	151	104	118	7,257	0.13	0.11
November	100	67	83	4,938	0.09	0.08
December	109	54	79	4,858	0.09	0.07
Per annum	5,060	32	390	282,937	5.03	0.37
1892.						
January	98	50	64	3,936	0.07	0.06
February	134	93	119	6,842	0.12	0.11
March	134	40	80	4,920	0.09	0.08
April 1 to 17	112	60	84	4,998	0.09	0.08
May 18 to 31	1,084	270	642	39,483	0.70	0.61
June	2,535	750	1,512	89,964	1.59	1.43
July	1,392	342	741	45,571	0.81	0.70
August 1 to 16	327	192	265	16,297	0.29	0.25

VIEW AT UPPER END OF TUNNEL ABOUT ONE-HALF MILE BELOW HEAD OF NORTH POUDRE CANAL, LARIMER COUNTY, COLORADO.

corporation composed of farmers who use the water, each share of the stock entitling the holder to a certain portion of the water in the canal, which can be used on as many acres as it will cover. The water right is worth from $10 to $15 per acre. Under this canal are a number of reservoirs owned by individuals or by corporations, water being stored in these until it is needed. Many other reservoirs are being constructed to be supplied by this and other canal systems, and greater dependence each year is placed upon these, several large ditches deriving their whole supply from water thus saved. For example, the Home Supply Company has two large reservoirs which are filled before the irrigating season begins and drawn upon to irrigate thousands of acres. Water thus held by storage has been exchanged for an equivalent amount from the stream to be used on higher grounds, while the stored water is allowed to flow down to prior appropriators below.

The Loveland and Greeley canal takes water from Big Thompson creek near Loveland, covering land on the north side of the stream, extending nearly to Greeley. The total length is 35 miles, average width 25 feet, and the cost was $140,000. The canal was begun in 1880 and used in 1883. Water rights are sold at about $1,000 each, entitling the owner to 1.44 second-feet of water to be used on an 80-acre tract. The annual assessment is about $15 on each water right. The principal crop raised is wheat, and next in order of importance is oats, then alfalfa and potatoes. It is stated that on wheat two irrigations of from 3 to 4 inches in depth each time will produce good crops in ordinary seasons, oats requiring a little more water, and alfalfa three irrigations of 5 inches each for three crops or cuttings.

Las Animas county is in southern Colorado, adjoining Colfax county, New Mexico, to which it is similar in many respects. The western boundary of the county is formed by the Culebra range, the divide between the head waters of streams flowing into the Arkansas and those tributary to the Rio Grande. In this part of the county are coal mines, and at the towns in the vicinity agricultural products find a ready market. Flowing easterly from the mountain range are a number of creeks and rivers, which after passing through a broad extent of the plain region empty into the Arkansas. Most of these streams have cut their channels to depths of several hundred feet into the higher parts of the plain, forming in this way high mesas whose surface is far above the reach of water.

The principal streams within the county are Apishapa river, Timpas creek, and the Purgatoire river with its branches. This latter stream is sometimes known as Las Animas river, and is commonly called by the ranchmen of the country the Picket Wire, a corruption for Purgatoire. It has its origin among the mountains and in its upper course discharges a large amount of water. In this higher part of the county, corn, beans, pease, potatoes, barley, and flax are raised without irrigation, but wherever possible ditches have been taken out to bring water to the arable lands along the small streams. Stock raising is the principal industry after mining. The agricultural population consists to a large extent of Mexicans, whose operations are carried on according to ancient methods and in a very laborious fashion.

The rivers after leaving the mountains flow for a large part of their course through canyons in the mesas and the quantity of water shrinks rapidly, so that the lower courses during the summer are almost dry. There are usually three or four weeks in late spring during which there is plenty of water. This is diverted upon low lands, and if these receive one good watering it is usually possible to obtain a fair crop of hay. Attempts to place dams in these rivers, especially in the Purgatoire, have not been successful on account of the severity of the floods. The irrigating ditches are mainly in the small valleys near the head waters of the streams and are rarely more than a mile in length. Many of them are very old, having been dug by the early Mexican settlers.

As examples of the largest ditches of the county may be given the following: the Duran and Vigil ditch takes water from the south side of the south fork of Purgatoire river about 6 miles south of Stonewall. It is 4 miles long, 3 feet wide, and cost $1,500. Water is diverted by means of a dam of brush and stone. The ditch is owned by neighboring farmers, who divide the water proportionally. In 1889 about 640 acres were irrigated, this being mainly in wheat, oats, and barley. Baca Extension ditch takes water from the north side of the Purgatoire river at Trinidad and flows in a general northerly direction. It is 19 miles long, 9 feet wide, and cost $12,000. Work was begun in the spring of 1888, and the ditch was completed the same year. On account of scarcity of water in the river a very small acreage was irrigated in 1889. The canal is owned by a corporation and the water is distributed to the shareholders. The annual cost of irrigation per acre is usually about $1, sometimes amounting nearly to $2 The principal crops raised are alfalfa, oats, and other cereals.

The Chititi ditch heads about 1 mile east of Trinidad and continues out on the south side of the Purgatoire river. The total length is 3 miles, average width 4 feet, and the cost was $2,000. The ditch was built in 1861. The water is used principally for the irrigation of garden vegetables, together with a small acreage of wheat, corn, and oats. In 1890 there were in all about 135 claims to water rights filed by the various ditch owners. The total amount of 37 of these claims, it is stated, came to 575 second-feet, while the Purgatoire river afforded about one-tenth of this quantity. This affords an illustration of the excessive amount of water claimed from these mountain streams and shows one of the difficulties of apportioning the supply to the many claimants.

Lincoln county is east of the center of Colorado, upon the eastern slope of the divide between the Platte and Arkansas basins, and thus includes a portion of the head waters of streams tributary to these rivers. Sheep and cattle raising is about the only industry, since the water supply is too small for any considerable development of agriculture. The streams shown upon a map of this part of the state are dry for many months of the year, but at long intervals they discharge an amount of water so great as to be almost beyond control. A little farming without irrigation has been attempted, but few crops have been successfully raised. Occasionally some corn is raised for fodder or a few vegetables for home use.

Water is obtained from springs and from wells from 10 to 100 feet in depth. There is an ample supply for cattle, and many of the wells appear to be almost inexhaustible by ordinary pumping machinery. There are a few small irrigating ditches in the county taking water during the spring at least from Big Sandy creek and from Steel fork of Little Horse creek, but both of these are dry at times when the water is most needed. Considerable water is obtained from the bed of the Big Sandy even in times of drought, and by making tight dams extending through the sand it is probable that a valuable perennial flow could be obtained.

LOGAN COUNTY is in the northeast corner of Colorado, upon the plains, its surface being of the general character of that of the adjoining state of Nebraska. The South Platte flows diagonally across the county from the southwest to the northeast corner, receiving in its course the waters of Pawnee creek and other streams which flow during the rainy season.

The conditions of agriculture are similar to those prevailing throughout eastern Colorado. Occasionally a crop can be raised without irrigation, but, with the exception of Indian corn, it is very uncertain and the yield per acre is small. The water supply is intermittent and irregular in character, sudden floods interrupting the long continued droughts. In the years 1885, 1886, and 1887 there was apparently an unusual amount of rain. Settlers flocked into the country and were fairly successful in raising crops. In the two years following there was a return to former conditions of drought, and many of the settlers becoming discouraged abandoned their farms. Those having irrigated lands have been able to make a living, although shortage of water has at times caused considerable losses.

The South Platte furnishes the greater part of the water used in irrigation. The river in this part of its course fluctuates greatly, being at one time a broad, swift stream and at another almost dry. The drainage area is so large that when the snows melt and there are continuous and widespread rains an enormous amount of water is brought into the main channel, but later in the season the almost innumerable canals and ditches along the tributaries divert so much that there is barely enough to moisten the broad, sandy channel. A number of canals and ditches have been built to irrigate land in this county, but these, although some have priority of rights over canals higher on the stream, can rarely obtain water after the spring flood subsides. Priority of right to the water is of little avail to a canal out upon the plains, from the fact that it is almost impossible to prevent the canals and ditches heading many miles above from taking all of the water, and if by the exercise of unusual police powers by the state officers an amount sufficient for this canal is left in the channel at points above, this water is soon lost by evaporation or disappears into the broad, sandy waste.

Water can always be found in the apparently dry bed of the river and many of its tributaries by digging from 1 to 20 feet, furnishing a supply apparently inexhaustible by pumping devices. By suitable dams or deep ditches a considerable amount of this water can be brought to the surface, but the expense is so great that it is still a matter of doubt as to whether it would be profitable. The irrigating systems at present take water from the river without the use of permanent dams, and therefore can receive a supply only when there is considerable water in the channel. There is a widespread complaint among the farmers to the effect that canal companies have sold water rights or shares which have proved to be valueless, and that many have been brought to the verge of ruin by the schemes of speculators, as well as by neglect and bad management of the canals.

A small amount of potatoes, corn, sorghum, broom corn, and beans is occasionally raised without the use of water, but the principal crops of the county are alfalfa and other forage plants raised mainly by spring and fall irrigation. Besides the irrigation ditches, some water is obtained by means of steam pumps and windmills, but the area of land cultivated by this means is inconsiderable. The largest canal of the county is the Pawnee, owned by the Pawnee Land and Cattle Company, taking water from the South Platte out upon the north side at a point above the town of Merino. The length of this canal is 23 miles and the average width about 30 feet. There is no permanent dam in the river, and the sand heaped up at the head works for diverting the water must be replaced after every large flood. The cost of the water right is stated to be $10 per acre, and the annual cost of cleaning and repairing canal from 12.5 cents per acre upward. The amount of water in the river is insufficient at times, largely owing to the fact that it is taken by other canals.

Beyond the Pawnee canal are a number of others, the principal of which on the north side of the river are the Lowline and the Sterling ditches, also the Arnett and the Iliff and Platte Valley canal, and on the south side of the river the Schneider and the Smith and Henderson ditches. The Lowline ditch is about 6 miles long, 12 feet wide, and the cost was approximately $2,000. The first cost of the water was about $100 for each 160 acres covered, and the annual cost is $6 for each 160 acres. The Sterling ditch No. 1 is about 16 miles long and 20 feet wide, and No. 2, below it, is 6 miles long. The Iliff and Platte Valley canal, heading 3 miles above Iliff, follows along the north side of South Platte river in a northeasterly direction at a distance of from 1 to 4 miles from the channel of the stream. The total length is 25 miles, the average width from 10 to 15 feet, and the cost was $55,000. There is no permanent dam in the river, earth levees being built when the stream is low. There are about 18 laterals about 2 feet in width and 1.5 miles long. The ownership is divided into 2,000 shares, 8 shares representing a water right for 80 acres. In 1889 and 1890 there was insufficient water in the river and the canal was allowed to get into bad order, so that a very small amount of land was irrigated, this being mainly for raising hay and for the meadows. The Schneider ditch, on the south side of the stream, is 9 miles long, about 10 feet wide, and the cost was approximately $5,000. Water is diverted by means of a wing dam of piles and lumber running out into the river 90 feet, and by a permanent dam of brush and earth about 300 feet in length. During low water temporary dams of sand are made across the entire width of the river, a distance of nearly one-half mile. The water right is valued at about $7.50 per acre and the annual cost is 25 cents per acre. At the time this ditch was built (1876–1877) there was apparently a great surplus of water during the irrigating season, but from that time the amount has gradually decreased until it is difficult to secure one-half the amount originally depended upon.

It is currently believed that patches of land can be brought under irrigation here and there throughout the county by the construction of storage reservoirs at suitable points and by the utilization of flood waters of the intermittent streams and springs. Progress in this direction is slow, as the people are too poor to invest an amount of money sufficient to thoroughly test such projects.

Mesa county is at the center of the western side of Colorado and includes the greater part of Grand River valley, the largest body of agricultural land in the western half of the state. The altitude of this valley is about 4,500 feet, and the climate is highly favorable for the production under irrigation of all fruits as well as of various cereals and of vegetables. The water supply is large, the discharge of Grand river being far in excess of any demands made upon it. The valley lands are on the north side of the river, extending from the state line easterly above the junction of the Gunnison, then southerly along the east side of the Gunnison up into Delta county. Irrigation is carried on not only in this valley but also along Plateau creek and its tributaries in the eastern end of the county, this creek rising on the broad plateau south of the Grand river and receiving tributaries from Grand mesa on the south and Battlement mesa on the north.

Although the Grand and Gunnison rivers carry an amount of water far larger than can be used upon the agricultural lands, yet, paradoxical as it may seem, the irrigators as a rule do not have sufficient water to save crops from loss. This arises mainly from the fact that the greater number depend upon water not from Grand river, but from the small streams draining the mesas. The expense of diverting the large river was so great that the early settlers were compelled to utilize the creeks or intermittent streams. These, having a rapid fall and being more easily controlled, were employed to their full extent before the larger streams were touched. The waters of the creeks of Mesa county are completely diverted during the summer and the appropriations along several of them far exceed the amount available. Thus it happens that while the waters of the Grand and Gunnison are flowing to waste farmers are losing crops, while some are constructing reservoirs to attempt to increase the summer discharge of small creeks.

Near Grand Junction, in the Grand River valley, canals have been taken out from the Grand river covering a portion of the arable lands. The principal of these is what is known as the Grand Valley canal, commonly stated to be owned by members of the Travelers Insurance Company of Hartford, Connecticut. The owners of this canal have absorbed into one system large ditches previously built and sell water rights to irrigators at prices of from $10 to $12.50 per acre, according to the conditions. The annual assessment is stated to be from 50 cents up to $1.50 per acre, while the annual cost of obtaining water to persons not owning water right is about $1.75 per acre. Many complaints have been made by farmers taking water from the canal of insufficiency of supply, owing either to the small capacity or to injury of the main line. At low stages of the river it is difficult to divert water into the canal and it is necessary to maintain cribwork to act as a dam in the stream.

There is opportunity for the construction of a large highline canal to cover 100,000 acres or more of this fertile land. Examinations have been made, showing that with the necessary capital it will be feasible to construct such a canal heading in the canyon above Grand Junction and sweeping around the northern edge of Grand valley north of and above the present systems and covering practically all of the valley. The great obstacles to the construction of such a system are the large amount of money required and the length of time which must elapse before agriculture can develop to the extent necessary to pay interest and annual expenses. Much of the soil through which a large canal must be built is of such a nature that some of the mineral constituents dissolve, causing the ground to sink, resulting in leaks or breaks in the banks. It is only after the water has been turned into the canal for two or three years that there can be a reasonable assurance that these disasters will not occur.

There have been no continuous gaugings of the amount of water in Grand river, the only measurements now at hand being those made by the Hayden survey in 1874. On September 23 the river above the mouth of the Gunnison was discharging at the rate of 4,850 second-feet, and it is stated that at the close of July of that year it must have been carrying at least 6,000 second-feet. Higher on the river, near the east line of Garfield county and below the mouth of Eagle river, the discharge in November, 1874, was 871 second-feet, and in September, at Hot Springs in Middle park, 802 second-feet, as shown in the tenth annual report of the United States Geological and Geographical Survey of the Territories, page 332. None of the small streams have been measured, but it is known that most of these become nearly dry from the latter part of June till the time of the fall rains. At the head of Kahnah creek, on the Grand mesa, work has been begun on a reservoir whose capacity is estimated to be about 600 acre-feet. Work on this has been very expensive, owing to the difficulty of reaching it, the only practicable means of transportation being by pack animals. There are many other places on Grand mesa where water could be stored if it is found profitable to do so. The ranchmen living along the creeks coming from the mesa state that it is necessary to resort to water storage if they are to save their crops in years of drought and to get summer cuttings of alfalfa. Some of this land could probably be covered by a canal from Gunnison river heading in the vicinity of Delta.

MONTEZUMA COUNTY is in the extreme southwestern corner of the state, adjoining Utah, Arizona, and New Mexico. The water draining from the mountain ranges within the county escapes either to the north in Dolores river or to the west through tributaries of San Juan river. Nearly all of these streams are of considerable size and furnish ample water for the land under cultivation, except perhaps at times of unusual drought. Progress in agriculture has been slow, owing to the remoteness of this area from large markets. Many irrigating ditches have been constructed by farmers, and there are also a few canals of notable size. The principal work of this kind is the canal system of the Colorado Consolidated Land and Water Company, taking water from Dolores river near the town of Dolores. There are two main lines, one running down on the west side of the river for a distance of about 6 miles, the other piercing a ridge by means of a tunnel 5,400 feet in length. This tunnel conducts the water directly from Dolores river into the drainage basin of streams tributary to San Juan river. From the mouth of the tunnel laterals extend northwest and southeast, covering lands north of and in the vicinity of the town of Cortez. The total cost of this system is estimated to have been $750,000. Water rights are sold at the rate of $12.50 per acre. This is in general plan one of the most remarkable irrigating systems of the state, the peculiar topography allowing of the diversion of water in this unique manner. It has been found difficult, however, to sell enough water rights to repay the cost of construction. Along Mancos river easterly from Cortez are a large number of ditches owned by individuals. These are as a rule under 5 miles in length and head at short intervals along the main stream and its tributaries.

MONTROSE COUNTY is on the western side of the state, adjoining Utah. The principal areas of agricultural land are along Uncompahgre river, which flows northerly across the western end of the county into Gunnison river. Water is taken out by many ditches and canals covering a great part of the lower lands, but the supply is by no means ample for the area under cultivation. If crops are planted early and reach maturity by the first part of July they can generally be secured without loss, the ditches up to that time receiving plenty of water. Later in the season, however, the streams diminish so that any one or two of the larger irrigating systems could use all the water to be had. While the Uncompahgre and its tributaries can not furnish a supply for the adjacent lands, the other streams to the east, Cimarron creek and Gunnison river, have more water than can be utilized upon their narrow valleys. Schemes have been proposed for bringing surplus water from these streams over into the valley near Montrose, but as yet the feasibility of the matter has not been determined. It will be necessary to resort to some measure of this kind or to water storage in order to bring all of the fertile lands under cultivation. The discharge of Uncompahgre river was measured by the state engineer during the summer of 1890 at a point about 8 miles above Montrose near the head of the Uncompahgre canal, the quantity during the period from July 10 to August 18 varying from 440 to 114 second-feet and averaging for July about 300 second-feet, for August 170 second-feet, for September 125 second-feet, and for October about 150 second-feet.

The climate and soils in the vicinity of Montrose have been found to be well adapted to fruit culture, apples, pears, peaches, plums, apricots, quinces, and grapes growing to perfection. The altitude of the valley is from 5,000 feet upward, but this does not result in lowering the temperature to an unfavorable extent. Owing to the scarcity of water and high annual rates grain raising is reported to be barely profitable, but hopes are centered in the orchards and vineyards. There are several canals of considerable size in the county, principal among which are those of the Montrose Canal Company, the Uncompahgre and Cedar Creek Company, the Delta Chief Company, and others. The works of the Montrose Canal Company take water out on the west side of Uncompahgre river about 6 miles above the town of Montrose. The main canal extends in a northwesterly direction, the total length being about 40 miles and the average width 16 feet. The total cost was $530,000. The land covered by the canal consists of mesas of various elevations, and as a consequence there are a large number of falls or drops along the line of the canal, one of these being 260 feet in height. On account of the excessive slope of the country and the character of the subsoil it is estimated that there is required 1 second-foot to irrigate 80 acres. The Uncompahgre and Cedar Creek Valley ditch heads on the east side of Uncompahgre river about 7 miles above Montrose and is continued in a northerly direction to the valley lands along Cedar creek. It is about 12 miles long and 10 feet wide.

MORGAN COUNTY is in the northeastern part of the state, lying on both sides of the South Platte. The water supply for irrigation is obtained from the river, which in this portion of its course occupies a broad, sandy channel, Owing to the diversions of water by the almost innumerable canals and ditches above, the channel is sometimes nearly if not quite dry. This was the case during the summer of 1888, 1889, and 1890 at times when there was greatest need of water.

The unusually low stages of the South Platte during the years above mentioned were due in part at least to the irregular fluctuations of climate. It is stated that before irrigation was introduced into this part of Colorado the river was known to be dry during the summer season, for instance, in 1863. Attempts are being made to supply the deficiency by storage reservoirs or shallow lakes filled during April or May. Several localities have been mentioned at which other works of this character might be constructed. The worst crop failure in the county was probably in 1890, when, owing to the apparently large amount of snow in the mountains, the farmers neglected to use water when it could be had early in the season and then were disappointed in the duration of the flood. On the high lands of this county, as in many other places in eastern Colorado and western Nebraska, farmers have taken up land and attempted to raise crops in the belief that the rainfall was steadily increasing each year, but their efforts have been without success.

The principal irrigating ditches in the county are: on the north side of South Platte river, the Weldon Valley, the Deuel and Snyder, and the Tetsel; on the south side: the Bijou, the Putnam, the Fort Morgan, and the Platte and Beaver ditches. The Weldon Valley ditch is 18 miles long, 20 feet wide, and cost about $64,000. Water is diverted by a wing dam of brush, stones, and sand, replaced in part every year. It is owned by an association of farmers under the ditch, to each of whom water is divided in proportion to his ownership. The Bijou canal is 55 miles long, 30 feet wide, and is stated to have cost $180,000. It was begun in 1888. (*a*) It is owned by a corporation, 6 shares of stock in which entitle the holder to water for 80 acres.

OTERO COUNTY is in southeastern Colorado, on the Great Plains, and is crossed from west to east by the Arkansas river, the largest source of water supply. This part of the state, including Pueblo county on the west and Bent and Prowers counties on the east, is a region of great irrigation enterprises, the topography of the country favoring or rather necessitating the construction of long canal lines. The Arkansas in this part of the state is a broad, shallow stream flowing through narrow bottom lands bounded by low bluffs. In order to reach the good agricultural land at the top of these bluffs long canals with gentle slope must be built. There are no perennial side streams from which water can be diverted by small, inexpensive ditches, the tributaries of the river entering within these counties being dry through a great part of the year and at other times discharging enormous quantities of storm water.

The united capacity of the canals is so great that it is a matter of doubt whether the river can supply them all when completed. The owners of some of the canals propose to supply deficiencies by the construction of reservoirs out on the plains. These are to be filled during the fall and winter months and by the excess water of spring floods, to be drawn upon later in the season when necessity arises. These reservoirs have not been in operation for a period long enough to demonstrate their success, nor are there measurements of the quantity of water flowing in the Arkansas sufficient to give data for computing the amount available for storage. Gaugings have been made for a number of years at Canyon city, as stated in the description of Fremont county, and at Pueblo, as noted under Pueblo county. In addition to these a few computations of the daily discharge of the river at La Junta have been made by the United States Geological Survey covering the period from May to August, 1889. The average discharge at this place during these months was 931 second-feet, the greatest flood amounting to 2,620 second-feet and the minimum flow, which occurred in August, was 55 second-feet.

DISCHARGE OF ARKANSAS RIVER AT LA JUNTA, COLORADO.

(Drainage area, 12,200 square miles.)

MONTH.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
May 20 to 31	1,[illegible]60	605	1,069	66,973	0.10	0.09
June	2,620	825	1,355	80,622	0.12	0.11
July	2,290	345	844	51,906	0.08	0.07
August	1,630	55	435	26,752	0.04	0.04

Several of the larger canals have dams across the river diverting all of the water, but at a point farther down stream there is usually an amount sufficient to partly fill the next canal. This was the case during the low water of 1889, when the Catlin canal apparently took all of the water, but at the dam of the Rocky Ford canal, 10 miles below, there appeared to be a stream of considerable size. There are a few small ditches in the county, deriving water from springs or from small storage reservoirs in depressions on the plains. The Purgatoire, which, flowing from the southwest, empties into the Arkansas at La Junta, is of little value for irrigation, since it is nearly dry during summer and is at all times liable to sudden floods. Measurements of the discharge of this stream are given under the description of Bent county.

---

[a] It was used in 1891.

No crops are raised without irrigation, but with it grain, hay, and fruits are successful. The cost of water rights from the large companies is usually from $10 to $12 per acre, and the annual charge for delivering water about $1.50 per acre. Many of the farmers state that their lands are heavily mortgaged in order to pay the $800 or $1,000 for an 80-acre water right, and with this debt, bearing interest at 10 per cent, they find difficulty in struggling along. The principal canals constructed in whole or in part are on the north side of the river, the Bob Creek canal, owned by the Colorado Land and Water Company, the Lake canal, and the Arkansas canal, of the Arkansas River Land, Reservoir, and Canal Company. On the south side of the river are the Rocky Ford Highline canal, the Oxford ditch, the Otero canal, the Catlin ditch, with the Fairmount extension, and the Rocky Ford Town ditch.

The Bob Creek canal heads about 2 miles west of Booneville, and after following along near the river for about 20 miles turns off toward the northeast. Construction was begun in February, 1890, and the canal was so planned as to carry 750 second-feet. It has been located for a distance of 118 miles and constructed for 65 miles at a cost of $270,000. The Arkansas canal heads 3 miles above La Junta and follows along the north side of the river at an average distance of from 2 to 5 miles. This canal was constructed at a point where a small ditch was formerly taken out for the purpose of irrigating a government Indian farm. The enlargement of this ditch was begun in 1888, and the canal thus constructed was extended for a distance of 113 miles, work being completed in 1889. The capacity for the first 7 miles is estimated to be 838 second-feet, then gradually diminishing. A dam 625 feet in length built of piling, timber, rocks, and earth has been constructed across the river, the height being 4.5 feet above the bed of the stream. During the first year or two enormous quantities of water have been required in order to saturate the lands, but it is expected that less and less will be used each year after the subsoil has been filled.

The Rocky Ford Highline canal, owned by the Rocky Ford Canal, Reservoir, Land, Loan, and Trust Company, takes water from the south side of the Arkansas river at a point in Pueblo county about 2 miles above Jackson. It follows along the river at a general distance of from 2 to 5 miles and has a total length of 78 miles. The total cost is reported to have been $225,000. It was begun in January, 1890, and used in the same year. No dam has been placed in the river, the head of the canal being below the bed of the stream. Shares in the canal are sold at $100 each, entitling the owner to water for 10 acres, or to 0.18 second-foot. The probable assessment for keeping the canal in repair is about 25 cents per acre. The canal has not been in operation for a time sufficiently long to determine this. For convenience the amount of water is usually expressed in miner's inches, and it is assumed that 1 second-foot equals 38.4 miner's inches. It has been estimated that at first 1.44 second-feet will be required for 80 acres, but that after 1 or 2 years this quantity will be sufficient for 100 acres, the tendency among the better class of farmers being to use a less quantity of water per acre and to cultivate smaller areas with greater care.

The Oxford Farmers ditch takes water from the river at a point about 7 miles below the above canal and 1.5 miles west of Nepesta, Pueblo county, and continues for a distance of 14 miles. The average bottom width is 14 feet, and the cost was $34,500. The canal was enlarged to its present capacity in 1889. The dam for diverting the water was made by driving piles across the river 4 feet apart and filling the spaces between these with brush held by barbed wire, the piles having been cut off to the level of low water. The canal is owned by a corporation composed of farmers and water is divided in proportion to the ownership of stock.

The Otero canal heads near the western line of the county about a mile above Fowler. It flows along between the Rocky Ford Highline canal and the river, being at an average of about a mile distant from the former. This canal as planned will be over 100 miles in length. It has an average width of 18 feet and is stated to have cost $200,000 for the first 66 miles. The canal was begun in March, 1890. As in the case of the higher canal, there is no dam in the river. Water is measured through an orifice 6 inches high under a 5-inch head. The cost of water right is $12.50 per acre and the annual assessment 15 cents per acre.

The Catlin ditch, owned by the Catlin Land and Canal Company, takes water from the Arkansas river at the mouth of Apishapa river or creek. It is at an average distance of from a quarter of a mile to a mile below the Otero canal, these being nearly parallel throughout their course. The canal is 26 miles long, 20 feet wide, and cost $55,000. It was begun in 1884, finished in 1887, and claims priority over the other canals in this district. The dam in the river consists of sheet piling and stone and is intended to be perfectly tight. Water is usually sold at the rate of $1.50 per acre each year, a permanent right costing $10 per acre, with about 15 cents per acre annual assessment. This canal has been continued toward La Junta by farmers who have built what is known as the Fairmount Extension.

The Rocky Ford Town ditch heads about 2 miles east of Catlin and continues in a southeasterly course through Rocky Ford to Timpas creek. It is 14 miles long, 12 feet wide, and cost $30,000. The dam in the river has been made of piles bound together by wire cable and has been made tight in part by use of brush held in place by barbed wire. The canal is owned by the persons who use the water, and the average expense per acre of maintaining the canal is estimated to be about 25 cents. The canal was begun and first used in 1874, being completed in 1888.

OURAY COUNTY is southwest of the center of Colorado and includes a portion of the head waters of the Uncompahgre river, which, flowing northerly through Montrose county, empties into the Gunnison, a tributary of Grand river. The greater part of the county is mountainous, but in Uncompahgre park and the valley to the north of this are considerable areas of grazing and farm lands. The water supply is large, and as a rule each irrigator has his own ditch. The general altitude of the farming lands is about 7,000 feet, and the climate is favorable for the production of all of the hardier fruits and vegetables. There is usually a sufficient rainfall to start the crops, irrigation not being employed until the young plants are well under way, as the water, coming directly from the mountains, is very cold. Oats, the principal crop excepting hay, are usually harvested in September, but if the season is unusually rainy they may not be cut until November. The arable land extends in a narrow strip along the river and tributary streams and is easily brought under irrigation. In most cases an excess of water is used, little care being given to its distribution over the fields. There is more or less waste, although a great part returns to the river by seepage.

PARK COUNTY is in the center of the state, and includes within its borders the broad basin like valley known as the South park. This lies at an elevation of from 8,000 to 10,000 feet and is surrounded on all sides by high peaks having an altitude of from 12,000 to 14,000 feet. The principal industry after mining is stock raising, the climate of the valley being too cold and arid for general agriculture. The only crops of importance are those for forage purposes, hay being made mainly from native grasses. A few potatoes and other garden vegetables are produced, some of these without irrigation. The rainfall during the summer is not sufficient to produce good crops of hay and it has been found necessary to practice irrigation. The water supply is large and well distributed, streams coming into the park from all sides, uniting finally to form the South Platte river. Along each of these streams are small ditches utilizing the greater part of the water, especially that which comes after the spring flood. Near the point where they issue from the mountains the streams are never dry, but further out into the park their flow becomes greatly diminished. As a whole there is seldom scarcity of water, but occasionally irrigators on the lower part of the stream do not obtain their share and complaint is made that there is little respect for priority of right.

The flooding of the meadows begins about the first of May, or from that time to the middle of the month, and is carried on continuously until it is time to cut the hay. Great quantities of water are used, much of it returning by seepage, since the evaporation at this altitude is relatively small. Projects have been set on foot to store a part of the floods of spring along streams whose waters have been overappropriated, and one company at least has been formed to utilize a lake as a reservoir. Water storage in and about the park is of far greater importance to irrigators in the counties along the South Platte than to the inhabitants of this region. The losses of crop here on account of scarcity of water are insignificant when compared to those down on the edge of the plains, and it appears essential to the future development of irrigation that works of this kind be constructed near the head waters, where water can be held at a comparatively small expense.

Few measurements have been made showing the amount of water available. During the Hayden survey in 1876 observations were taken showing that on July 3 the middle fork of the South Platte at a point about 6 miles below Fairplay discharged 388 second-feet, and that above the mouth of the Little Platte on June 29 the discharge was 367 second-feet. Below the mouth of Twin creek the discharge on June 23 was 1,015 second-feet, and down at the foot of the canyon on September 8 was 1,400 second-feet. In July, 1887, the state engineer of Colorado established a gauging station near Deansbury in the canyon of the river about 26 miles south of Denver, the drainage area here being 2,600 square miles. The results obtained at this place give the total discharge from the South park and show the amount of water available for use on the lands below. During four years the greatest computed discharge at this place was 788 second-feet and the least 90 second-feet. The average discharge during the 6 months from May to October for the years 1888, 1889, and 1890 was 329 second-feet.

PHILLIPS COUNTY is in the northeastern part of Colorado, south of the South Platte, from which it is separated by Sedgwick county. It is situated upon the rolling prairie, where there are no perennial streams, water being derived from wells of from 100 to 300 feet in depth, usually pumped by means of windmills. Irrigation is not practiced on account of the lack of water. Frenchman river rises in this county, but the channel here is dry during a great part of the year, though in Nebraska it becomes a perennial stream. The soil of the county is remarkably rich, and the climate, though dry, is enjoyable. Were it not for the prevailing droughts the county would be brought under complete cultivation. Many farmers were induced to settle here upon representations that the droughts were diminishing, but after four or five years' ineffectual struggle a number have been compelled to abandon their claims.

PITKIN COUNTY is south of Eagle and includes the head waters of Roaring Fork, a tributary of Grand river, above or south of Fryingpan creek. In the valley along Roaring Fork the altitude is nearly 8,000 feet and the climate is too severe for agricultural products except the hardier cereals and forage plants. Water for irrigation is taken out of the streams which come from Elk mountains on the southwest and from those rising in the Saguache range on the east. The principal of these are Castle, Snowmass, Capital, and Woody creeks, the water supply in which is ample for present needs. At Aspen, the principal mining town in this vicinity, is a good market for everything that can be raised. The ditches of the county are small, mainly under 5 miles in length, and are owned and controlled by the irrigators.

PROWERS COUNTY lies on both sides of the Arkansas river on the eastern side of Colorado adjoining Hamilton county, Kansas. On the west is Bent county, from which come large canals bringing water from the river far out upon the prairie lands. Under these canals are hundreds of thousands of acres to which water can be taken if it is to be had. It has been found difficult, however, to obtain an ample supply at this distance from the head of the canals and many complaints have been made by farmers concerning the management and distribution of the water. It is stated that the ditch companies operating in the Arkansas valley of eastern Colorado have sold more water rights than can be made good by the supply available and have misled settlers by statements regarding probable crops and prices. Many of the farmers have mortgaged their land to the companies and must pay the interest and part of the principal at stated periods. There is no penalty imposed on the company for failure to furnish water, and thus farmers state they are left in the position where, not receiving the water paid for, they can not raise crops and pay off the mortgages. The feeling against the speculators or capitalists who have organized these schemes has been especially bitter in this and adjoining counties toward the west.

This county is unusually well provided with canals and ditches, and wherever they are successfully conducted lands are rapidly being brought under cultivation. The great question, therefore, is as to the extent and permanence of the water supply, and all interest centers on the feasibility of providing suitable storage. There are already under way a number of projects involving the construction of reservoirs in depressions adjacent to channels from which it is hoped to obtain water during times of flood. Many attempts have been made to raise crops without irrigation, but usually without success. The situation here has been similar to that in western Kansas, where during the years 1886 and 1887 settlers poured into the country and after struggling against drought became discourged to a greater or less extent, many leaving their homes and possessions to avoid starvation. Fair crops of sorghum have been raised, and also under favorable conditions potatoes have done well, but as a rule little confidence can be placed in crops not watered regularly.

On the north side of the Arkansas, and about 8 miles from the river, is the lower part of the Arkansas canal project owned by the Arkansas River Land, Reservoir, and Canal Company, mentioned in the description of Bent county and shown on the map. Nearer the river, and heading 1 mile west of the county line, is the Amity canal. South of the river is the project known as the Colorado and Kansas canal, from which a few water rights have been sold. Below this, and heading near the western county line, is the Bed Rock ditch, supplying Lamar, and in turn down the river are the Lamar Land and Canal Company's ditch, the Black ditch, the X Y Irrigating canal, and a number of others.

The canal of the Bed Rock Mutual Ditch Company heads about 8 miles west of Lamar and takes water out on the south side of the river to lands in the vicinity of that town. The total length is 11 miles, average width 10 feet, and the cost was $18,000. The ditch was begun in March, 1889, and used to a small extent during that year. It is owned by a corporation, four shares in which entitle the owner to a water right, namely, sufficient water for 80 acres. The average cost of these water rights per acre was about $5 and the annual assessment 15 cents. The X Y Irrigating ditch heads about a mile north of Carlton and carries the water easterly for a distance of about 14 miles. The average bottom width is 8 feet, and the cost was $15,000. Water is diverted by a temporary brush dam. The ditch was begun in the fall of 1889 and used in the following year, from 400 to 500 acres being irrigated.

PUEBLO COUNTY is southeast of the center of the state lying on both sides of the Arkansas in the part of its course where it changes from a mountain stream to a broad, shallow river, with gentle fall. There are within the county many small ditches taking water upon narrow valley lands and farther down the stream the head works of large canals designed to cover thousands and even hundreds of thousands of acres. The Arkansas receives both from the north and from the south a number of tributaries heading in the foothills. Taking these in order down stream, there are, on the north side of the river, Turkey and Fountain creeks, and on the south, Rock creek, St. Charles river and its tributary, Greenhorn creek, and Huerfano river. Each of these, like the main stream, supplies water, especially near its head waters, to a number of irrigating ditches.

On the western edge of the county among the mountains, as, for example, near Rye and other localities where the altitude is between 6,000 and 7,000 feet, some of the cereals are raised without irrigation, but taking the county as a whole this is exceptional unless there happens to be an unusually large amount of snow during the winter. The quantity of water available for irrigation falls far short of the demands made upon it. This is especially notable in the case of the tributaries of the Arkansas. In the main stream itself within the the limits of the county there is a relatively large amount of water at all times of the year, but all of this, except during the floods, is needed by the canals covering lands in Otero and Bent counties. Measurements of the amount of water in the Arkansas have been continued through several years at the gauging station at Canyon, as given in the description of Fremont county. A shorter series of gaugings has always been made at Pueblo and also at Rock canyon, about 9 miles above the city.

The measurements of the Arkansas at Pueblo were carried on under the direction of the state engineer of Colorado during 1885, 1886, and 1887. The maximum discharge at this place was, in May, 1886, 7,659 second-feet, and the minimum recorded was about 400 second-feet. The average discharge throughout the year, estimating the amount for the winter months, in 1886, was 1,441 second-feet and in 1887 was 1,323 second-feet. The total area of the catchment basin above this point is 4,600 square miles, and this amount of water discharged from the basin is equivalent to a depth over the whole area of 4.3 inches and 3.9 inches in the two years, respectively.

The measurements made at Rock canyon by the United States Geological Survey during May, June, July, and August, 1889, showed that the greatest discharge during that time was 4,375 second-feet, and the least was 405 second-feet. The average for these 4 months was 1,210 second-feet. Attempts were also made to measure the amount of water in the Huerfano at the outlet of the Cucharas canyon, about 20 miles southerly from Pueblo, but at the times visited, in June and July, 1889, the bed was almost dry, the discharge probably being from 3 to 5 second-feet. Measurements of St. Charles river, or rather creek, at a point in the canyons about 22 miles southwest from Pueblo showed that on September 10 the discharge was only 3.5 second-feet, this discharge coming in equal quantities from the north and south forks.

There have been several attempts made within the county to increase the water supply at various points by laying drains beneath the surface of channels dry throughout a great part of the year. Along Fountain creek at a place below points where the water has been completely diverted, an irrigator has laid a box drain starting at the surface and continuing up stream, with a rise of only about 1 inch per 100 feet. This box is 1,300 feet in length, and finally reaches a depth of 10 feet below the surface. The statement is made that the discharge from this, even during dry weather, is upward of 4 second-feet. In other localities, especially in the vicinity of Pueblo, storage reservoirs have been made and other works of this class are projected.

RIO BLANCO COUNTY is near the northwestern corner of the state, north of Garfield county, of which it formerly was a part. It includes the greater part of the area drained by the White river, this stream flowing through the county in a general westerly course. Much of the surface consists of high plateaus, deeply eroded and cut into cliffs and hills. On these plateaus, or mesa lands, is some grazing, but there is very little water, especially during the hot weather, springs or pools being found only at long distances from each other, and often in deep canyons or narrow gorges. The White river, for a great part of its course, flows through a narrow valley, the arable land seldom attaining a width of a mile. Near the old White River agency the valley expands, and also farther down the stream, at Powell park and Raven park, near Rangely. The river receives a large number of tributaries from the plateau lands on each side, most of these streams having cut canyons into the soft rocks. The water in these during summer diminishes and generally ceases to run, standing in pools or disappearing altogether. Along the principal tributary, Piceance creek, coming in from the south, is a strip of arable land, much of which has been brought under irrigation. The water supply, like that of Routt county, is large for the present amount cultivated, but as farming operations are extended there will be difficulty in the distribution of the water.

The main stream discharges an amount far greater than will be needed to bring all of the tillable land along its valley under irrigation. The expense of constructing canals, however, to use the water is so great that the settlers have been unable to take them out. They have built a few ditches from the river, but most of the small irrigating systems depend upon the tributaries, on account of the ease with which the ditches could be built from these at the points where side streams enter the valley. Thus, although the water supply of the county is large, yet that which can be utilized by present methods is far below the needs of the cultivators.

The greater part of this county is included within water district No. 43, a portion of division VI, which embraces the drainage basin of Green river in Colorado. The ditches in this district were adjudicated shortly before the census year. Most of the ditches in use during the census year were small, less than 2 miles in length, a few being longer. The Coal Creek ditch, taking water from the creek of that name above Meeker, is 5 miles long, 5 feet wide, and cost $2,500. It was built in 1886 and used in 1887. It is owned by private parties, who, in 1889, irrigated 200 acres, nearly all of this being in wheat, oats, and hay. The Meeker Bridge ditch takes water from White river at Meeker, and covers land on the south side of the river. It is 2 miles long, 3 feet wide, and cost about $800. About 100 acres were irrigated in 1889, this being in cereals, potatoes, and grass.

RIO GRANDE county contains some of the largest irrigating canals in the United States, the water being derived from the Rio Grande and carried to the north, east, and south across the broad San Luis valley into the counties of Saguache, Costilla, and Conejos. The banks of the river are low and beyond them the ground falls away gently toward the northeast and southwest, rendering diversion of the water a matter of moderate cost or of relatively slight expenditure of labor. It has thus been possible for many farmers to take out ditches, in some cases the first cost of the main ditch not exceeding $1.50 per acre supplied, the laterals or distributing ditches aggregating as much more. Only a small proportion of the vast extent of valley land has as yet been cultivated by irrigation, but the diversions or appropriations of water are so complete that there is little more to be had even in wet years. At this high altitude, Del Norte being 7,865 feet above sea, the crops consist mainly of the cereals and of hay.

The principal canals head at or near Del Norte and at points farther down stream. [a] Besides these are numerous ditches taking water from tributaries of the Rio Grande, from Embargo, Pinos, and other creeks.

---

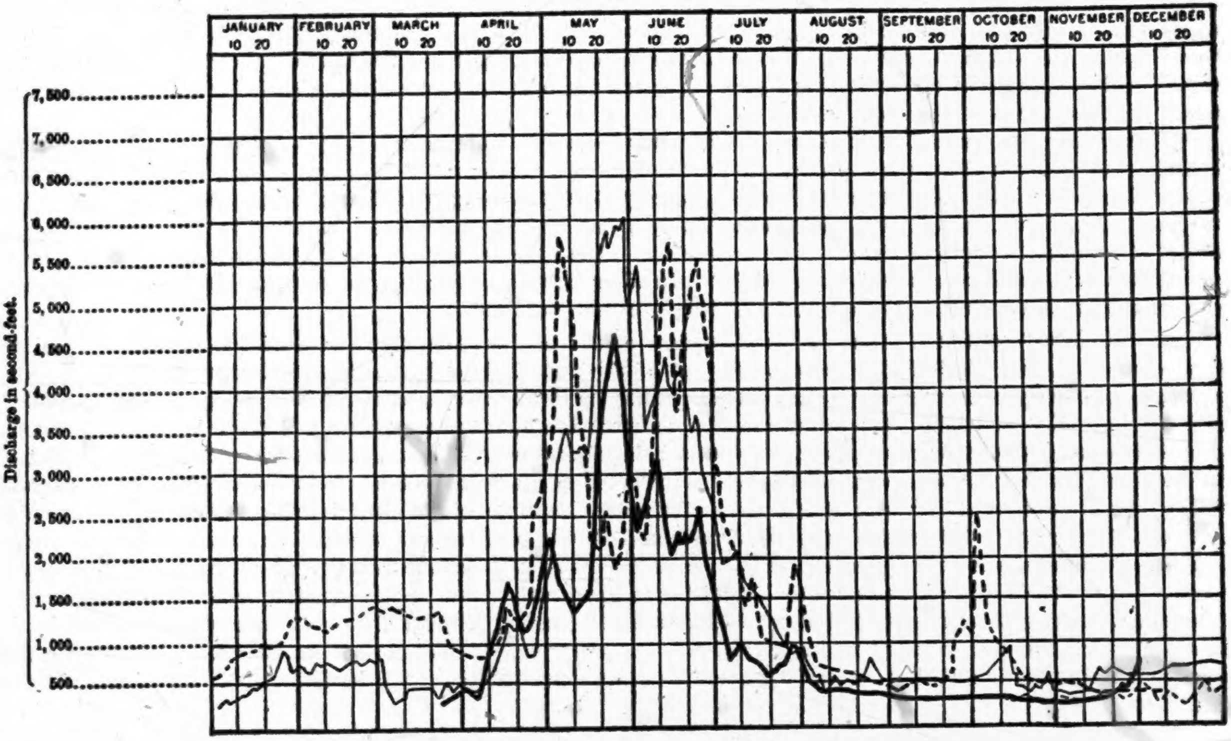
[a] The quantity of water in the river above the head of the large irrigating systems has been measured at a point about 3 miles above Del Norte since 1889, the results of these measurements being shown diagrammatically in the accompanying figure. In this diagram the light broken line indicates the quantity of water

The principal irrigating systems are, as shown by the map, on the northern side of the river, the Del Norte (later known as the Rio Grande) canal, Midland ditch, Farmers Union, North Star, and Fish ditches, the San Luis

---

in 1889, the light continuous line that in 1890, the heavier broken line that in 1891, and the heavy continuous line that in 1892. The gagings for a series of years are also given.

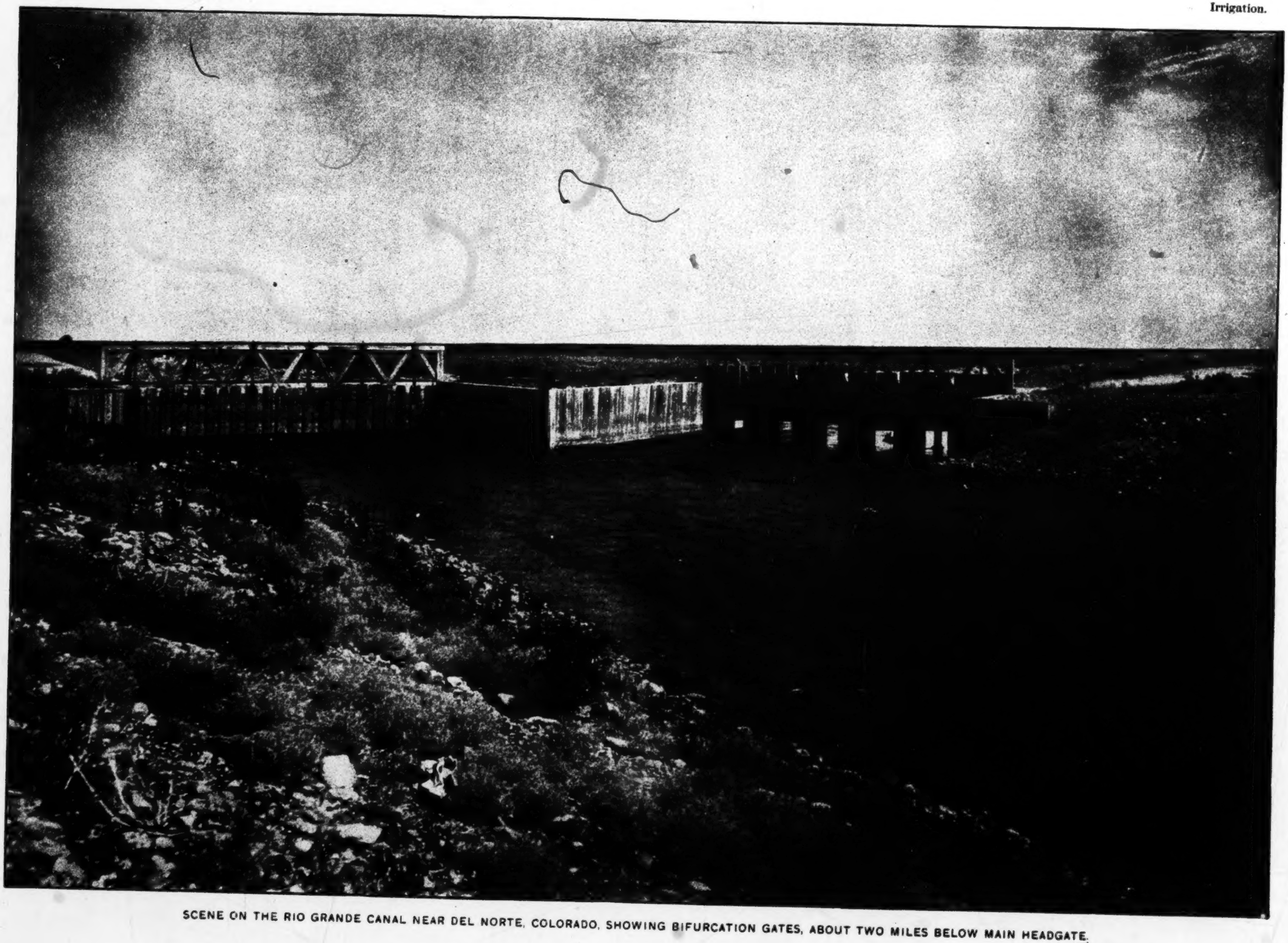
DIAGRAM OF DAILY DISCHARGE OF RIO GRANDE ABOVE DEL NORTE, RIO GRANDE COUNTY, COLORADO.



DISCHARGE OF THE RIO GRANDE AT DEL NORTE, COLORADO.

(Drainage area, 1,400 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
October 11 to 31	345	214	278	17,097	0.23	0.20
November	364	290	319	18,980	0.25	0.23
December	364	200	281	17,281	0.23	0.20
1890.						
January	1,000	326	552	33,948	0.45	0.39
February	896	745	796	44,178	0.59	0.57
March	842	404	487	29,950	0.40	0.35
April	1,380	404	913	54,323	0.73	0.65
May	5,930	1,990	4,331	266,356	3.57	3.09
June	5,555	2,550	3,807	226,516	3.03	2.72
July	2,260	862	1,515	93,172	1.25	1.08
August	930	450	612	37,638	0.50	0.44
September	450	326	383	22,788	0.31	0.27
October	862	307	470	28,905	0.39	0.34
November	610	345	478	28,441	0.38	0.34
December	670	475	565	34,747	0.46	0.40
Per annum	5,930	307	1,242	900,962	12.06	0.89
1891.						
January	1,320	670	990	60,885	0.81	0.71
February	1,410	1,196	1,294	71,817	0.96	0.92
March	1,460	930	1,280	78,720	1.05	0.91
April	3,160	796	1,410	83,896	1.12	1.01
May	5,650	1,860	3,245	203,027	2.70	2.34
June	5,555	2,190	4,146	246,687	3.31	2.96
July	3,565	862	1,693	104,119	1.39	1.21
August	1,460	404	663	40,774	0.54	0.47
September	1,234	290	527	31,356	0.42	0.38
October	2,475	450	844	51,906	0.69	0.60
November	450	308	374	22,253	0.30	0.27
December			325	19,967	0.27	0.23
Per annum	5,650	290	1,403	1,014,426	13.56	1.00
1892.						
January			300	18,450	0.25	0.21
February			300	17,250	0.23	0.21
March 23 to 31	345	290	316	19,434	0.26	0.23
April	2,400	345	1,047	62,296	0.83	0.75
May	4,710	1,510	2,605	160,207	2.15	1.86
June	3,160	1,152	2,187	130,126	1.74	1.56
July	1,074	554	740	45,510	0.61	0.53
August	610	308	444	27,306	0.38	0.32
September	308	243	262	15,589	0.21	0.19
October	290	243	259	15,928	0.21	0.18
November	829	243	360	21,420	0.29	0.26
December	1,074	863	922	56,703	0.76	0.66
Per annum	4,710	243	812	590,219	7.92	0.58



SCENE ON THE RIO GRANDE CANAL NEAR DEL NORTE, COLORADO, SHOWING BIFURCATION GATES, ABOUT TWO MILES BELOW MAIN HEADGATE.

and the Kenilworth canals; on the south side the Monte Vista, Rio Grande and San Luis, Empire, Centennial, and other canals. The Del Norte canal, owned by the Rio Grande Land and Canal Company, heads one-half mile above Del Norte and, leaving the river almost at right angles, runs northeasterly into Saguache county. The total length is about 35 miles, the width at the head 60 feet, narrowing gradually until at the terminus it is 12 feet wide on bottom. The characters of canal and of the country traversed are best shown by the accompanying illustration. Besides the main ditch there are 378 miles of laterals, of a bottom width of 8 feet and upward. The total cost of this system has been placed at $700,000. Water rights are sold at the rate of $5 per acre near head of canal or $12 per acre near the lower end. When rented the charges are from 50 cents per acre to $2 per acre per annum, while the annual assessments on water rights are from 10 cents to 50 cents per acre, according to distance from head gate. Much of the land under these canals is rapidly becoming saturated, so that the question of drainage is assuming more importance than that of irrigation. Crops are raised on a number of farms without irrigation, sufficient water being supplied by percolation or "subirrigation".

The Farmers Union ditch takes water from the northern side of the Rio Grande about 5 miles east of Del Norte, and, like the canal above mentioned, it runs northeasterly. The total length is 24 miles and the average width 35 feet. Work was begun in 1887, the system not being complete in the census year. The ditch is owned by farmers, who divide the water according to the number of shares held by each.

The ditch of the Monte Vista Canal Company, formerly known as the Citizens ditch, heads on the south side of the Rio Grande about 8 miles below Del Norte. It is 44 miles long, 45 feet wide at head, 40 feet wide at 30 miles from head, and 14 feet wide at terminus. The total cost is estimated to have been $480,000. Water rights are sold at from $8 to $12.50 per statutory inch, the annual charge or assessment per statutory inch being from 20 cents to 55 cents. From 80 to 100 of these inches are usually allotted to 160 acres, but after the land is irrigated for a time this quantity is generally found to be excessive. As on the north side of the river, some of the lands are becoming saturated and drainage questions are becoming of prime importance. The Empire canal heads about 2 miles east of Monte Vista, extending from this point in a southerly direction, being thus from 3 to 5 miles east of the Monte Vista canal. It is 30 miles long, 60 feet wide at head, and 20 feet wide at lower end. The cost of the canal has been placed at $400,000. Work was begun in 1882, the canal being completed to Alamosa creek in 1884 and to Conejos river in 1889. In this latter year the water supply was very poor and the crops were below the average.

ROUTT COUNTY, occupying the northwestern corner of Colorado, has the largest area of any county in the state. It extends from the continental divide westward to Uinta county, Utah, and includes the greater part of the drainage basin of the Yampa river. The service consists of deeply eroded plateaus, or mesa lands, broken by hills and mountain ranges. The altitude of the plateaus ranges from about 7,000 to 8,000 feet, the mountains on the east rising to heights of 11,000 feet and over. The population is scattered, but is mainly in the eastern part of the county in the natural parks near the head waters of the streams. Cattle raising is the principal industry, and small areas are tilled on many of the cattle ranches, the greater part of the water being used, however, for hay and meadow lands.

In nearly all parts of the county it is necessary to irrigate crops and trees in order that they may live through the summer. In the eastern end, however, near Steamboat Springs, and at points higher on the Yampa river the cereals and hardier vegetables are raised without the application of water, the precipitation in the vicinity of the mountains being probably greater than that over other portions of the county. The methods of irrigation are crude, since it has been practiced for but a short time. Nearly all of the ditches have been built by neighboring farmers. In the parks and at other places where the rivers have not cut deep canyons it is comparatively easy to divert the water and cover large areas of valley land. The mesas, however, forming the greater part of the county, are nearly all above the reach of water, and, although having a soil often of great fertility, they are valueless for agriculture. At points where streams can not be diverted by ditches attempts have been made to pump water by hand, horse, and steam power, but without success, the value of the products being too small to justify the required outlay.

Within the county there are no railways or similar methods of transportation, the nearest shipping points being in southern Wyoming, 40 miles or more north of the county. As a consequence the products are for consumption by ranchmen and their families. Large quantities of hay are raised, in a few places alfalfa being successful. Two crops of this have been cut, but on account of the cold nights and early frosts the yield is small. Timothy is reported to thrive remarkably, and under irrigation the native bluestem grass does well for a few years.

Although the county is thinly settled, it is stated that in the more favorable localities much of the land has been brought under irrigation that can readily be supplied, and settlers have taken up every piece of arable ground near springs or perennial streams from which water can be diverted. There are as yet few contests concerning the division of water, although occasionally a farmer at the lower part of the valley has complained of the increasing diversions made above him. There still remain localities where lands can be brought under irrigation by building canals from the larger streams, but such enterprises require the expenditure of more money than the present inhabitants possess. In a few instances high water ditches have been built, these receiving water only in times of flood, and at a few points wheels for elevating the water have been tried. Estimates of the water supply from the Yampa were made by Henry Gannett, as stated in the Hayden report for 1876, page 338. A gauging made about the middle of November at the ford of the wagon road from White River agency to Rawlins gave a discharge of 664 second-feet, this being at about the lowest stage of the water.

The ditches of the county are short, most of the streams utilized having sufficient fall, so that each farmer or group of irrigators can divert water without long canal lines. Water is taken mainly from Fortification creek and its tributaries, Elk river, and the upper part of the Yampa. A description of a few of the larger ditches will serve to give the general character of all. The Pleasant Valley ditch is on the west side of Yampa river and heads about 15 miles above Steamboat Springs. It is 7 miles long, 7 feet wide, and cost about $1,200. Work on it was begun in 1889, and water was used in the succeeding year. The Woolery ditch is on the south side of Yampa river, heading about a mile below Steamboat Springs. It is 3 miles long, about 8 feet wide, and cost $800. The supply of water is ample, and each person having ownership in the ditch uses as much as he wishes. The principal crops are wild hay, with a little timothy, oats, wheat, and barley.

The Reid ditch is on the south side of Yampa river, heading about 5 miles above Hayden. It is 7 miles long, 10 feet wide, and cost $3,000. Work was begun in 1882 and completed in 1889. It is owned by ranchmen, and is used to irrigate hay and oats. In this valley there are 3 other ditches, similar in many respects. The Big Cut ditch takes water out on the north side of Yampa river, about 3 miles above the town of that name. It is 4 miles long, 8 feet wide, and cost $3,500. It was begun in 1886 and finished in 1890. At this point the fall of the river is so slight that it is expensive to divert water, but the supply is ample. Little Bear Creek ditch takes water from the creek of this name, about 5 miles above the point where it empties into Fortification creek, covering land between these two streams. It is over 4 miles long, 3 feet wide, and cost $2,000. The water supply is fairly good except in the latter part of summer. (a) This county and the adjoining county, Rio Blanco, with the exception of small areas, are included within water division VI, this comprising lands within the drainage basin of Green river, or rather within that of its two principal tributaries, White and Yampa. This has been subdivided into water districts numbered 43, 44, 54, 55, 56, 57, and 58. District No. 43 embraces all of the White river drainage, and therefore includes nearly the whole of Rio Blanco county, as previously stated. The remaining districts, excepting 56, are within the watershed of the Yampa and include all of Routt county, excluding a small portion in the southeastern corner, where the county lines extend into the drainage basin of Grand river. The irrigators using water from the Yampa and its tributaries have been very dilatory in securing an adjudication of their water rights or in taking the first steps toward putting their claims upon record as required by state law. In these somewhat remote localities there has been great ignorance as to the objects and value of adjudication of water rights, and even considerable hostility toward such work.

In each water district there are reservoirs commenced or projected. These are usually small and intended to furnish water only for one or two ranches each. Both Routt and Rio Blanco counties are, as previously stated, usually well watered, especially in their eastern parts, and it is safe to assert that the area of land now irrigated can be greatly increased in the future. In the eastern end of Routt county the supply of water if properly conserved and distributed is probably in excess of the irrigable land. In the western parts of both Routt and Rio Blanco counties, for land which can be irrigated directly from the main rivers, White, Yampa, and Green, there is a superabundance of water, but along the tributaries in this part of these counties the irrigable land is probably in excess of the water supply. In the northern and western portions of Routt county, along Little Snake river, there is still a large amount of water unutilized, but it is probable that the supply will fail before all of the irrigable lands can be covered.

Both Routt and Rio Blanco counties were settled by stockmen, who allowed their herds to roam over the government lands. Stock raising is still the most important industry, but the conditions are gradually changing, the herds being smaller and, as a consequence, better kept. The owners are making better preparation every year for raising hay for winter feed, increasing the area of meadows and uplands in forage crops, these depending upon

---

[a] A general report upon the condition of irrigation in this and the adjoining county of Rio Blanco has been made by J. C. Kennedy, C. E., under date of March, 1893. The following figures are given by Mr. Kennedy as a close approximation of the number of ditches, their aggregate length, and the acreage irrigated in 1892, the length being that already constructed and not the mileage projected:

DISTRICT NUMBER.	Number of ditches.	Aggregate length in miles.	Acres irrigated.
43 (Rio Blanco county)	142	210	14,700
44 (Routt county)	42	78	7,400
54 (Routt county)	20	46	5,400
55 (Routt county)	15	36	2,900
56 (Routt county)	17	31	2,800
57 (Routt county)	47	101	12,600
58 (Routt county)	134	273	28,300

irrigation. Wild grasses have formed the principal acreage thus watered, but alfalfa and cultivated grasses are displacing these. Next in importance to the forage crops are oats, potatoes, barley, rye, and wheat, all of which are being largely grown.

SAGUACHE COUNTY includes the northern part of San Luis valley or park, the northwestern corner extending over Cochetopah hills, and including a small part of the head waters of Gunnison river. The western boundary of the county is formed by the Sangre de Christo range, beyond which is the valley of the Arkansas. From these mountains and hills streams flow inwardly toward San Luis park, and entering upon the edge of this vast plain tend to form swamps or lakes. Some of the streams unite and flow toward the south, but all ultimately disappear by evaporation from the marshy lands. Since the settlement of the country, however, farmers have begun to divert the water from these streams by means of ditches heading near the foothills and carrying the water out in every direction over the nearly level surface.

The altitude of this part of the valley is from about 7,700 feet to 8,000 feet and over, but the climate, though somewhat cold, is not too severe for most of the ordinary agricultural products of temperate regions. Certain of the cereals and grasses, with water properly applied, reach a high degree of excellence, and potatoes, as well as other common vegetables, are raised with profit. Few, if any, crops can be raised without irrigation except on low lands wet by seepage from streams or canals. Water is obtained for use in the county from creeks and from the Rio Grande, being brought out by large canals heading not far from Del Norte, as mentioned in the description of Rio Grande county. The accompanying illustration shows the size of one of these canals and exhibits the character of the country traversed as well as the methods of controlling and dividing the water for the two main branches. The methods of irrigation in use, especially along the various creeks, are very wasteful of water, and the best results are seldom attained. Far larger areas could probably be cultivated and a heavier yield per acre obtained by the employment of the same amount of water more systematically utilized. Most of the men owning large ranches turn the water out upon the meadows in spring and let it run continuously with little attention until about the time to cut hay. Most of the lands are thus flooded, some spots receiving too much water and others not enough. During the census year cereals were raised on 4,267 acres, of this there being in oats 2,570 acres, with an average production of 24.95 bushels per acre, and in wheat 1,396 acres, with an average production of 20.78 bushels per acre.

In the northwestern corner of the county is Cochetopah creek, flowing northerly from the hills of that name into Gunnison river. Along this creek is a narrow valley at an altitude of about 9,000 feet. Water is taken from this stream by the various ranchmen and carried by ditches along the sides of the valley, the method of irrigation being similar to that practiced in most of these isolated localities where water is abundant. Openings are made in the side of the ditch every hundred feet or so, allowing a portion of the water to escape when the ditch is full. The banks soon become covered with grass, so that the water does not cut them away or enlarge the openings. At the beginning of the irrigating season water is turned into the ditch, and a day or two later the owner rides along the ditch to see that water is coming from the various openings, and whether the high places are being properly wet. After water has been flowing in this way for from one to two weeks the head gate of the ditch is shut for about 2 weeks, allowing the ground to be warmed and dried by the sun, and then water is turned on again. By this method there is a considerable area of waste land in all the meadows, water not reaching all parts alike. The grass raised in this way is in some places native, in others timothy or redtop, all of these furnishing excellent feed for cattle.

SAN JUAN COUNTY, in the southwestern part of the state, includes a portion of the high mountain area north of La Plata county. The altitude at the lowest point is over 8,000 feet, this being in the narrow valley of Las Animas river. Agriculture is not attempted, or at least during the census year there were no farming operations worthy of enumeration. Although there are no arable lands in these high valleys, yet there are apparently many places at which water can be stored for use on farming lands farther to the south, and thus the county may have considerable importance indirectly for the development of agriculture in other localities.

SAN MIGUEL COUNTY is one of the long, narrow counties in southwestern Colorado, extending from the mountains in Ouray and San Juan counties west to the Utah line. Agriculture has made but little progress, the first crop of any considerable size being produced in 1888. The water supply in the eastern end, near the mountains, is large, but the streams as found at lower altitudes are mainly small, or are difficult of diversion. There is an enormous extent of mesa land, much of it fertile, but it is doubtful whether water can be brought to it. A number of ditches have been dug covering lands along San Miguel river, these being owned by the farmers. One corporation, the Naturito Ditch Company, has diverted water from Middle and Little Beaver creeks, selling water rights to irrigators at the rate of $10 per acre.

SEDGWICK COUNTY is in the extreme northeastern corner of Colorado, north of Phillips county, to which it is similar in many respects. The South Platte flows diagonally through the county, but during the summer and until November it is usually dry. Even at this time, however, water can be found in the sandy channel by digging a few feet below the surface. Many attempts at farming made in this county have not been successful, and the population steadily decreased from 1887 to 1890. Some of the farmers state that they have tried to raise crops and have failed three or four years in succession. Hopes are entertained that by means of suitable dams or deep ditches the water in the bed of the South Platte can be brought out upon some of the lower lands. It is extremely doubtful, however, whether the quantity realized will repay the expense, for the passage of the water through the sands of the bed of a stream is comparatively slow, and when these are partially drained the inflow is very small. Surveys have been made, however, in the hope of bringing the water out and carrying it far easterly into Nebraska. The wells from which water is at present obtained are in many instances from 250 to 300 feet in depth, are tubed with 2-inch pipe, and pumped by means of windmills. Persons not owning wells buy water at a few cents per barrel.

SUMMIT COUNTY includes a narrow valley through which flows Blue river, a tributary of Grand river. Along the river are small areas of arable land, but the climate is too cold for general agriculture, frosts occurring nearly every month in the year, the altitude of the lower lands being from 8,000 to 9,000 feet. Besides its mineral wealth the county is valuable for stock raising, there being good grazing on the lower slopes. Nearly every ranch in the valley is provided with a small irrigating ditch, the water being used for raising hay. The supply is large, especially from the streams on the south side of Blue river, the principal drawback being that mine tailings are discharged into some of the creeks, lessening the value of the water for irrigation purposes.

WASHINGTON COUNTY is in the northeastern part of the state, including a portion of the rolling prairie south of the South Platte river, the northwestern corner coming down to this stream. The principal towns are near the railroad in what is known as Yuma valley. No irrigation is carried on except near the South Platte on account of the absence of perennial streams. The only source of water supply for the greater part of the county is from wells dug or drilled to depths of from 100 to 200 feet or over. There are a few scattered springs, but these are employed almost exclusively for watering cattle, the surplus being too small for purposes of irrigation.

Cereals and vegetables grow with great luxuriance until the latter part of June or first of July, when the drought begins to affect them. The yield even in good seasons is less than that upon irrigated land. Nevertheless farming in connection with stock raising affords a living to many settlers, and an occasional good year goes far to make up past losses. The crops in 1889 were not particularly good, and in 1890 they were almost an entire failure, about the only thing of value being corn fodder. Attempts have been made to secure water by means of deep wells. One at Akron is 900 feet in depth and has a small amount of water in the bottom. It is stated that the railroad company drilled to a depth of 2,300 feet without success. Along the south side of the South Platte river are several irrigating ditches which cross the county line, the principal of these being the Platte and Beaver, heading in Morgan county, and below this are the Johnson and Edwards ditches, owned by irrigators.

WELD COUNTY is in the northern part of Colorado, east of Larimer county, east of the foothills of the Rocky mountains, and upon the western edge of the Great Plains, the average altitude being about 5,000 feet. The principal town is Greeley, near which are located the irrigating systems deriving water from the Cache la Poudre, as mentioned in the description of Larimer county. South Platte river flows into the county from the south, and during its course receives the waters of St. Vrain creek, which rises in Boulder county, also of Big Thompson creek and Cache la Poudre creek, both coming from Larimer county. Near the junction with that latter creek South Platte river turns toward the east and finally enters Morgan county. The water supply of the county is obtained not only from South Platte river, but also from the creeks above mentioned, together with several minor tributaries.

Irrigating canals and systems of ditches have been constructed in such numbers and with a capacity so great that in the aggregate they could carry far more water than the river and its tributaries supply in ordinary seasons. As in the other counties of this part of the state, there is complaint that farmers have been induced to purchase water rights from companies unable to furnish water except during flood seasons, and, although the supply is far below the necessities of irrigators, new canals are being built and old ones enlarged. The lands at present irrigated are mainly near the river and its tributaries, and thus form but a small proportion of the surface of the county. Back from the streams are thousands of acres with a rich soil, but lying at an altitude too great to be reached by irrigation ditches even if water could be had.

Without irrigation little or nothing can be raised. Attempts have been made at various times to farm without a water supply, but usually this has resulted in loss. Some of the lower lands receive sufficient moisture by the seepage from canals, so that irrigation of the surface is not required. Instances are given where the seepage is so great that lands formerly cultivated are now used for pasturage, and others are ruined by standing water. By thorough systems of drainage in connection with irrigation water could be saved for use on other lands and injury of this kind prevented. In the northern part of the county and above the canals from the South Platte and its tributaries very little farming is now attempted. In 1885 and 1886, through the efforts of land agents, many persons were induced to settle upon the high lands in this county, as well as in the localities farther to the east, it being asserted that the rainfall was increasing and would be sufficient for the crops. Many of these so-called "rain belters", after trying several years, were literally starved out, having lost everything in the struggle against drought. Others have succeeded in making a living by working for cattle companies or for the owners of irrigated land.

The water supply on lands remote from the streams above mentioned is derived from wells of 100 feet or more in depth or from shafts sunk into the dry channels of intermittent streams. The amount obtained in this way is, however, too small for purposes of irrigation, being sufficient only for cattle and domestic purposes. Along Crow creek, which comes into the county from the north, are a number of ditches, and a little irrigation is practiced, but the amount of water has diminished year by year, owing probably to diversions in Wyoming. To supply the city of Cheyenne, for example, a dam has been built, extending to bed rock and thus taking out the water percolating through the sands and gravels. Farther down the stream channel, in Colorado, enough water returns, however, to supply shallow wells of from 2 to 5 feet in depth. This may be taken as an example of the streams upon the edge of the plains, water being found in their beds a few feet from the surface.

It has been found in this county, as in many others, that the farmers succeed in raising crops with far less water than was used in former years. Not only has the ground been to a certain extent saturated, but the farmers gain skill by practice and observation. Nevertheless the demand for water is rapidly increasing, and as a rule the amount available for the use of each farmer has decreased. It is asserted that farming is not as profitable as it was before so many ditches were built, the farmers who came first not being able, though having law and custom on their side, to secure sufficient water. The increase in the number of irrigating canals, without system or regulation, has thus tended toward scarcity of water and occasional loss of crops.

Relief from crop losses can be gained in part by greater care and economy in the distribution and use of the water supply and by storage of spring floods. The losses from the reservoirs on low ground, however, are very great, and the many unsettled questions regarding water rights cause the irrigators to hesitate in building large storage reservoirs among the mountains. A small amount of water for irrigation is raised by means of steam pumps, and the vacuum pump made at Greeley has been largely employed for this purpose. Several farmers state that they have not been able to raise crops profitably by this means on account of the cost of fuel. There are also a few artesian wells in the county, but these discharge very small quantities of water.

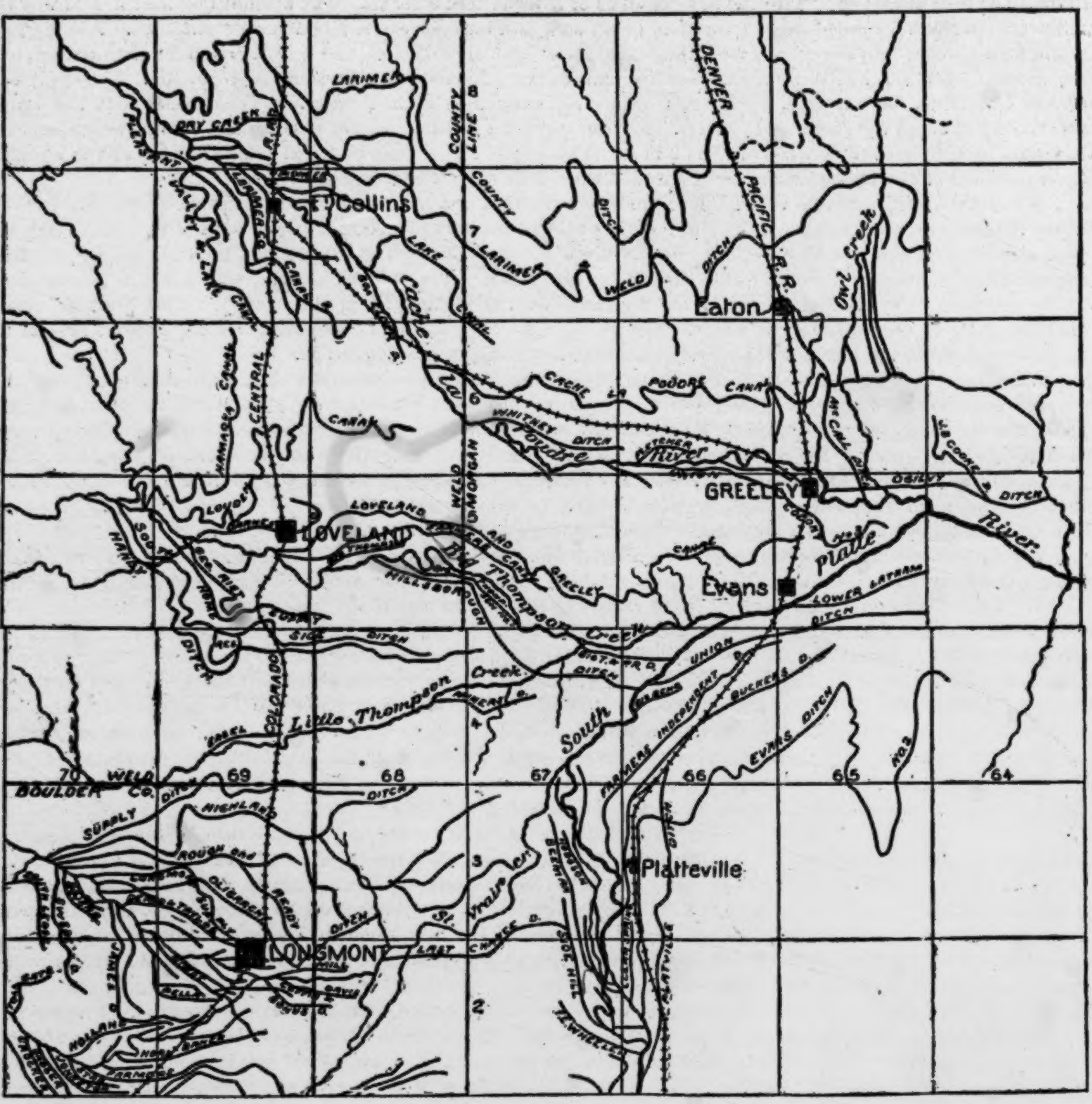
Weld county comprises portions of water districts No. 1 to 5, inclusive. No. 1 includes the streams coming into the South Platte east of Greeley, No. 2 the land along the South Platte above St. Vrain creek, No. 3 the land watered from Cache la Poudre creek, No. 4 from Big Thompson creek, and No. 5 from St. Vrain creek. The principal canals in these divisions and in this county are given below in geographic order down stream, taking the tributaries in succession. On the east and south side of the South Platte river are the Folsom, the Platteville Irrigating and Milling Company's, the Platte Valley, Buckers, the Farmers Independent, the Union, and the Lower Latham ditches. On the west side of the South Platte river above St. Vrain creek are the Brighton, the Fort Lupton Bottom, the Side Hill, the Beeman, and the Hodgson ditches. Along St. Vrain creek are many ditches extending into the county from Boulder county, the principal of these being the Lower Boulder, the Matthews, and the Highland ditches, and further down the Last Chance ditch. From Big Thompson creek come others, among which may be mentioned the Hillsboro ditch and the Loveland and Greeley canal.

In the vicinity of Greeley, and taking water from the Cache la Poudre on the south side, is Union Colony canal No. 3, and north of this stream the Larimer County ditch, the Larimer and Weld canal, the Cache la Poudre canal, or No. 2, the Whitney, the Ogilvy, and other ditches. East of Greeley the irrigating ditches are comparatively small and unimportant, but almost any one of the canals mentioned above would be considered a factor of great importance in the development of most of the counties of the arid region. The great number of expensive irrigating systems in this county makes it difficult to select representative works for description, but the following statements may be taken as fairly typical.

The Platte Valley canal heads on the east side of the South Platte river and carries water in a northerly and northeasterly direction. The total length is 30 miles, the average width 20 feet, and the cost was about $50,000. It is owned by a corporation, selling water rights to farmers for $1,000, each right being intended to convey 1.44 second-feet of water for use on 80 acres. The Union ditch heads on the east side of the South Platte river, about 8 miles above the town of Evans. The total length is 16 miles, and the average width for the first 10 miles is 16 feet, and beyond this point is 10 feet on bottom. The total cost of the canal was about $25,000. It was begun in 1874 and first used in 1880. Water is diverted from the river by a dam made of brush, held in place by piling, having in the center gates 30 feet in width. The canal is owned by a corporation composed mainly of land holders, the ownership being divided into 250 shares, and the water distributed in proportion to the number of shares held. The shares are worth $100 each, and it is stated that the water distributed to the owner of 10 of these will irrigate 80 acres. The annual assessment has varied from $2 to $10 per share.

The Beeman ditch takes water from the South Platte on the west side, about 5 miles above Platteville, carrying it out in a general northerly direction. The total length is about 7 miles, width 10 feet, and the cost was $2,000. Water is diverted by means of a brush and dirt dam. The ditch is owned by farmers living under it and using the water. There are 40 shares, the ownership of a share entitling the owner to open his measuring box admitting the water to a width of 6 inches. For 2 shares the box is opened 12 inches wide; 3 shares, 18 inches, the depth of water in all measuring boxes being the same. Water is scarce in some years and crops are lost, in 1889 there not being a full crop on any of the land.

MAP OF IRRIGATING CANALS IN THE VICINITY OF GREELEY, WELD COUNTY, COLORADO.


LARIMER
DRY CREEK
PLEASANT VALLEY & LAKE CANAL
Ft. Collins
R.R.
COUNTY LINE
8
7
LARIMER COUNTY
LARIMER & WELD
DITCH
LAKE CANAL
Cache
la
Poudre
River
DENVER PACIFIC R.R.
Eaton
Owl Creek
CACHE LA POUDRE CANAL
6
WHITNEY DITCH
McCALL DITCH
GREELEY
OGILVY DITCH
River
Platte
Evans
LOWER LATHAM DITCH
CENTRAL
CANAL
WELD
MORGAN
LOVELAND
HANDY
DITCH
Big Thompson Creek
HILLSBOROUGH
GREELEY
SIDE DITCH
COLORADO
Little Thompson Creek
4
UNION D.
FARMERS INDEPENDENT D.
BUCKERS D.
EVANS DITCH
No. 2
South
70
69
68
67
66
65
64
WELD
BOULDER Co.
SUPPLY DITCH
HIGHLAND DITCH
ROUGH AND READY DITCH
OLIGARCHY
3
St. Vrain Cr.
Platteville
LONGMONT
LAST CHANCE D.
2
SIDE HILL
HOLLAND
FARMERS

The Lower Boulder ditch takes water from Boulder creek, a tributary of St. Vrain creek, and carries it out on the south side in the vicinity of the town of Erie. The total length of the main ditch and extension is about 18 miles and the average width 10 feet. The cost was approximately $10,000. The ditch is owned by farmers, who divide the water among themselves. The Last Chance ditch is taken from St. Vrain creek below the mouth of Boulder creek, being on the south side of the stream. The length is 6 miles, width about 12 feet, and the cost was approximately $8,000. As in the case of other ditches, the water is divided among the owners in proportion to the amount paid in.

Union Colony canal No. 3 takes water from the south side of the Cache la Poudre, about 5 miles above Greeley. It is 10 miles long, 10 feet wide, and cost, probably, $30,000. Water is diverted by means of a permanent wooden dam. The water is measured out of the canal over weirs 8 inches deep, provided with a slide open to a width proportional to the amount to be discharged to each user. The ditch and the right to use the water is owned by the grantees of the Union Colony of Colorado and is managed by trustees. The water supply is often scanty, and care must be taken to guard against loss of crops.

The Larimer and Weld canal takes water from the Cache la Poudre, near Fort Collins, running out on the north side of the river. The total length is 50 miles and the average width 25 feet. The total cost was $150,000. Water is diverted by a wing crib dam 177 feet long and 4 feet high above bed of stream. The canal is owned by a corporation, selling water rights at $1,200 for 80 acres. The annual assessment is about $10 for each of these rights. The Cache la Poudre Irrigating canal, formerly known as Union Colony canal No. 2, takes water from the Cache la Poudre, about 8 miles below Fort Collins, carrying it easterly a distance of nearly 30 miles. The average width is 30 feet, and the cost was about $200,000. It was begun in 1870, being used in the following year. The dam in the river is permanent, being made by driving piles in the bed of the stream and covered with plank and stone. The above described canals, as previously stated, form but a small part of the irrigating system of the county and are perhaps not extraordinary or more worthy of note than others.

YUMA COUNTY is east of Washington county, of which it was formerly a part. The north fork of the Republican river rises in this county, and flowing easterly into Dundy county, Nebraska, becomes a stream of considerable size. Three small ditches have been taken from the stream, one near the town of Wray and another covering the land in the vicinity of Laird. The greater part of the land cultivated, however, depends upon rainfall for its water supply. Nearly all kinds of cereals and vegetables are raised, but the yield per acre is often small, as the rainfall is uncertain as to time of occurrence. Many of the settlers not being able to make a living by agriculture have had to abandon their claims and leave the country.

Over the greater part of the country water is obtained by means of wells upward of 200 feet in depth. Some of these are reported as discharging water during or after heavy storms. The north fork of the Republican flows continuously throughout the year, being fed by springs in the sand hills, and the stream is singularly free from sudden floods. The ditches follow the narrow valley, the Wray and Chief Creek ditches being on the south side and the Laird ditch on the north. The total length of these is about 15 miles, the average width 10 feet, and the cost when completed will probably be $10,000. The water supply is stated to be ample and the soil of great fertility. An annoyance in operating the ditches consists in the fact that great quantities of sand are blown into them, especially during the month of March, if the soil is dry.

IDAHO.

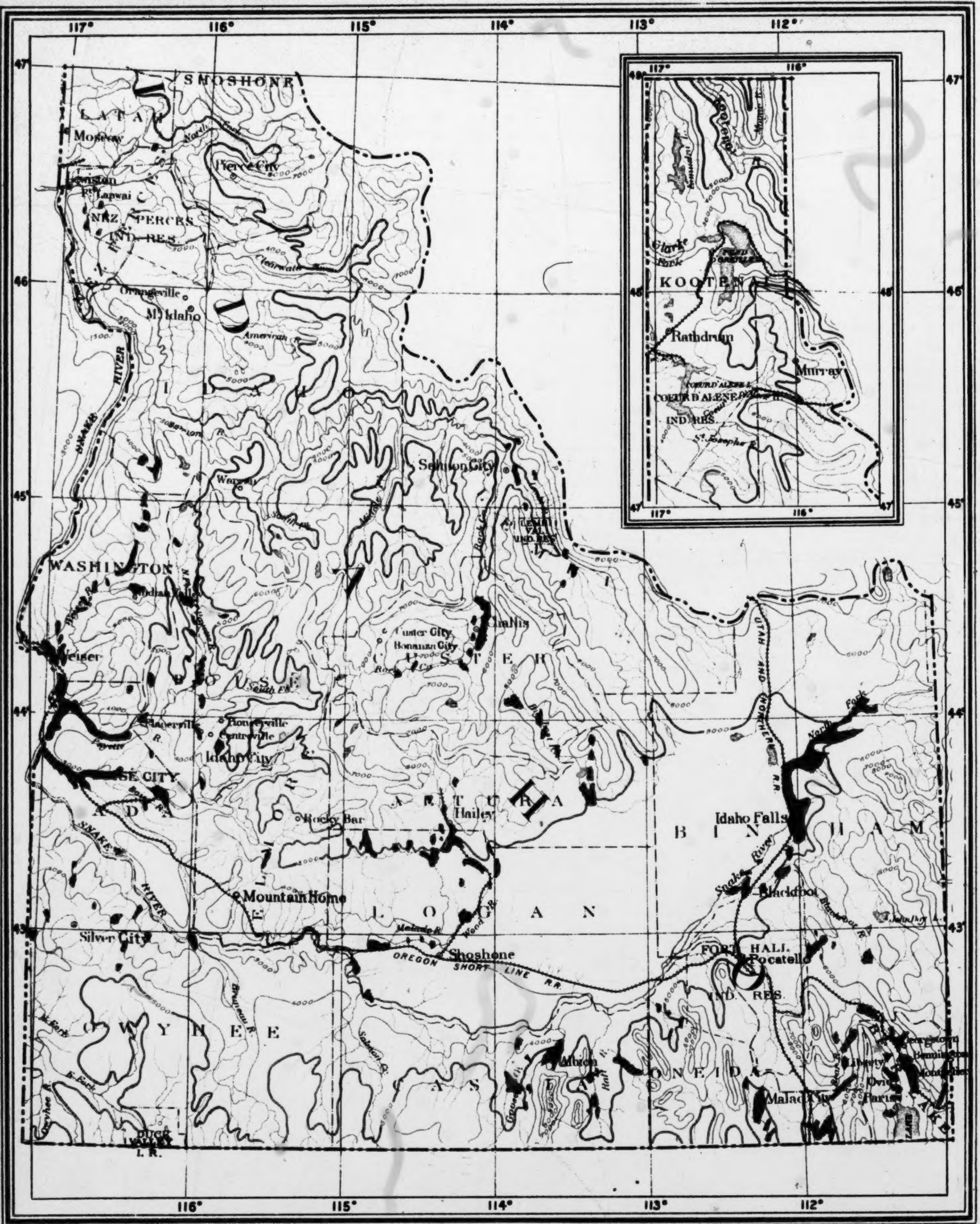
Total population (average per square mile 1.00)		84,385
Number of owners of farms (7.82 per cent of population)		6,603
Number of irrigators (65.47 per cent of farm owners, 5.12 per cent of population)		4,323
Area of state, land surface (84,290 square miles)	acres	53,945,600
Area irrigated in census year	do	217,005
Area of all farms, 46.56 per cent improved	do	1,302,256
Cereals raised in census year, including 16 acres in buckwheat and 1,092 acres in rye	do	98,175
Barley, average production, 23.64 bushels per acre	do	10,004
Corn, average production, 18.13 bushels per acre	do	1,362
Oats, average production, 26.70 bushels per acre	do	21,997
Wheat, average production, 18.47 bushels per acre	do	63,704
Alfalfa	do	31,895
Total value of all farms, including land, fences, and buildings		$17,431,580
Estimated total value of the farms irrigated in whole or in part		$10,091,000
Estimated value of all farm productions (sold, consumed, or on hand) for 1889		$3,848,930
Estimated value of productions, as above, from farms irrigated in whole or in part		$2,806,000
Average size of irrigated farms	acres	50
Average size of irrigated farms of 160 acres and upward	do	270
Per cent of acreage of irrigated farms of 160 acres and upward to total acreage irrigated		26.49
Average size of irrigated farms under 160 acres	acres	39
Average first cost of water right per acre		$4.74
Average annual cost of water per acre		$0.80
Average first cost per acre of preparation for cultivation		$9.31
Average value of irrigated land, including buildings, etc., in June, 1890, per acre		$46.50
Average annual value of products per acre in 1889		$12.93

In addition to the facts given in the above statement, it has been ascertained by comparison with similar statistics for other states that Idaho is fourth in the number of irrigators, seventh in area irrigated, and eighth in average size of farms. In nearly all respects as regards value of farms and of products it occupies an intermediate position, in no one item standing near either extreme of cost or value of land and water, and thus the conditions, especially those in southern Idaho, may be regarded as fairly typical of the state of irrigation in the arid region during the census year. The average annual cost of water was somewhat low, from the fact that most of the ditches then in actual use were owned by the irrigators and the larger systems charging a certain amount per acre each year did not then play an important part.

TOPOGRAPHY.

The state of Idaho lies on the southwest side of the Bitterroot mountains, and extends from the crest of this range southward across the Snake river and westward to the same stream, being bounded by it until the point is reached where it turns nearly west to flow into the Columbia. The peculiar wedge-shaped form of the state, broad on the southern end and tapering almost to a point at the north, is due largely to the peculiar topography of the region. The Bitterroot trends in a northwesterly direction, while the Snake river, which in a general way governs the other boundaries of the state, takes a widely different course. It rises south of the end of the Bitterroot mountains in the continental divide near the Yellowstone park, and issuing from these mountains the main stream flows southwest, then west, northwest, and finally north, thus describing roughly a great arc of a circle. The greater part of the state of Idaho lies within this area, being bounded on the upper side by the mountains and on the lower by this great half circle made by Snake river.

On the south the state lines do not follow the Snake river, but take in a portion of the country on the south side of the river, and in order to coincide with lines of latitude and longitude they have been laid out independent of the topography. Thus, it happens that in the southeastern corner an important portion of the Bear river drainage is included within Idaho, although topographically it belongs to the drainage of the Great Salt lake. As an apparent offset to this gain on the part of Idaho, the head waters of the most important tributaries of the Snake lie beyond the eastern borders of the state of Wyoming. With these exceptions, it may be said that Idaho lies within the drainage basin of the Columbia and almost wholly on the basin of its great tributary, the Snake.


117°
116°
115°
114°
113°
112°
47°
46°
45°
44°
43°
SHOSHONE
LATAH
Moscow
Lewiston
Ft. Lapwai
NEZ PERCES IND. RES.
Pierce City
Clearwater
Orangeville
Mt. Idaho
American
SNAKE RIVER
WASHINGTON
Weiser
Warren
Salmon City
Challis
Custer City
Bonanza City
CUSTER
BOISE
Placerville
Pioneerville
Centreville
Idaho City
BOISE CITY
ADA
ALTURAS
Hailey
Rocky Bar
Mountain Home
ELMORE
LOGAN
Silver City
Shoshone
OREGON SHORT LINE R.R.
OWYHEE
CASSIA
Albion
ONEIDA
Malad City
BINGHAM
Idaho Falls
Blackfoot
FORT HALL IND. RES.
Pocatello
Paris
Montpelier
Liberty
Ovid
Bennington
Georgetown
BEAR LAKE
UTAH AND NORTHERN R.R.
DUCK VALLEY I.R.
KOOTENAI
Rathdrum
Murray
COEUR D'ALENE IND. RES.
Pend d'Oreille
Clarks Fork
St. Joseph R.
IDAHO

IRRIGATED ■

MAP OF IDAHO SHOWING AREAS IRRIGATED IN 1889.

A conception of the topography of Idaho in its broad features can be had by picturing a great range of mountains extending in a northwesterly and southeasterly direction, sending off about its center spurs toward the west. Imagine then the base of these mountain masses toward the south and west buried beneath great deposits of lava, which form extensive plateaus, or high plains, stretching out in every direction, and descending by broad terraces or gradual slopes until broken by isolated groups of mountains. The rivers which flow out from the high backbone of the state on reaching these plains have cut for themselves deep channels, and often disappear into narrow gorges or canyons, continuing on their way to the sea at a depth of from 200 to 500 feet or more beneath the general level of the plains. These two great topographic divisions of Idaho, the mountains and the high plains, afford a convenient classification for a consideration of the agricultural resources of the state, since in the mountains the rainfall is generally sufficient to mature crops, while around the bases of the mountains and out on the plains it is exceptional for anything to be produced without irrigation. The mountain counties, especially those at the north end of the state, do not need irrigation, except in rare instances for the gardens and orchards in the lower valleys, while the counties south and west of the mountain mass, with less rainfall, require the artificial application of water for almost every crop.

Although irrigation is necessary for the raising of crops outside of the mountain areas, it must not be supposed that the land is barren. Much of it in its original state was covered by the rich, though dry, "bunch grass", which has afforded pasturage for enormous herds of cattle ranging from the plains far up in the mountain valleys. Next to mining stock raising has been the great industry, although in the past few years, with the introduction of irrigation on a larger scale, the cultivation of the soil has assumed importance.

The Great Plains, though consisting for the most part of lava and having a surface occasionally broken by craters and buttes, contain in the aggregate many hundreds of thousands of acres of land, that by the application of water may be rendered wonderfully productive. Besides the high plains, there are places where the largest streams have eroded valleys of considerable width, as, for instance, along the Boise and Payette rivers, and it is here that the greatest agricultural development has taken place. There are also localities, as, for example, at the forks of the Snake river, where the streams have not yet succeeded in cutting through the lava, and where river water can be brought out upon the surface of the plain. West and south of this latter point, however, stretches out the vast expanse of broken and slightly rolling lands, to water any considerable part of which will require great irrigation systems.

WATER SUPPLY.

The water supply of Idaho as a whole is large, and there are a number of rivers whose perennial flow amounts to hundreds or even thousands of second-feet, but unfortunately the peculiarities of topography above described render it impossible to utilize the whole of this water, since the greater part of it sinks rapidly beneath the general level of the agricultural lands. This is the case with the waters of the Snake, the Salmon, and the Clearwater. The smaller streams, which rise mainly in the foothills and flow out toward the lower lands, have a very small summer discharge, from the fact that they drain lower mountains, and their waters for the greater part of the year sink into their pervious channels. In order to render these small streams useful in the highest degree it will be necessary to hold their waters from March and April until later in the season.

As an example of the fluctuation of the streams of the state in their discharge month by month, the monthly percentages of the total annual flow are given in the following table. These percentages were obtained from the results of stream measurements made by the United States Geological Survey.

DISTRIBUTION OF FLOWING WATER AND OF RAIN IN IDAHO.

MONTHS.	Average monthly discharge of upper tributaries of Snake river. (Per cent.)	Average monthly discharge of lower tributaries of Snake river. (Per cent.)	Average monthly precipitation at Boise, Idaho. (Per cent.)
Total	100.00	100.00	100.00
January	3.9	1.4	17
February	4.0	4.3	12
March	4.0	27.0	13
April	7.7	30.0	11
May	24.0	24.7	9
June	21.0	6.4	5
July	11.0	1.7	1
August	6.0	0.6	1
September	5.0	0.5	2
October	4.5	0.7	7
November	4.5	1.2	8
December	4.4	1.5	14

To illustrate the difference in character between the upper and lower tributaries of the Snake, the two classes have been separated and the percentages computed for each. As examples of the upper tributaries, the streams on the extreme west in Bingham county have been taken, and for comparison with these is given the average distribution of water throughout the year in the Weiser in Idaho and the Owyhee and Malheur, which flow into the Snake from Oregon. These latter rivers flowed from lands of lesser altitude, and, as shown by the percentages, the greater part of the water came down in March, April, and May, over four-fifths of the water of the entire year being discharged in these three months. The waters from the higher mountains, as shown by the first series of percentages, were more evenly distributed through the year. The main discharge was, however, in May and June, nearly one-half the entire amount for the year coming in those months. The smallest amount discharged in any one month was in the eastern rivers, nearly 4 per cent, while in the case of those farther west, at a lower altitude, the discharge fell in September to one-half of 1 per cent.

It is instructive to compare the distribution of the available flowing water with that of rain. For this purpose it is convenient to take the normal monthly rainfall for Boise city as published by the signal office. Taking a range of 16 years, the average annual rainfall was 15.61 inches, this being distributed by months as shown in the table. From December to April, inclusive, two-thirds of the entire amount for the year fell; in May and June about one-seventh, and in July, August, and September only one twenty-fifth. While the greatest amount of rain falls during the winter months, the water which is available for agriculture is found in the smaller streams in early spring and in the larger streams a few weeks later.

The irrigators who depend upon water from the lower mountain slopes have an excess during April and May, as shown by the above table of percentages, but in June the supply diminishes rapidly, and toward the end of that month the streams become almost, if not quite, dry. The methods of using water must, to a certain extent, conform to this state of things, and therefore while the water is plentiful it is applied to the ground even though the plants may not need it at that time. The ground, however, must be thoroughly saturated in order to store up moisture for future needs. Those farmers who are so fortunate as to have ditches leading from streams flowing out of areas of high mountains depend upon receiving water later in the season, since the discharge of the streams during June is nearly as great as that for the month previous, and even during July the streams maintain a discharge above that of the average for the year. Moreover, during August and September the waters fall not very far below the mean annual discharge, and thus with a less wide range of fluctuation these rivers and creeks are far more valuable to agriculture.

Water storage is of the utmost importance, especially on the small streams, showing a great range in discharge from month to month. Certain irrigators have already begun the construction of small reservoirs at various points and have attempted in their own way to hold over some of the flood waters of March and April into the dry time in the latter part of June and July. They state that there are many valleys which, in their opinion, are suitable for holding water, and there is every probability that many works of this character will be built. The problem, however, of greater general interest at present is that of utilizing the large rivers by bringing them out upon the high plains through which they flow.

DITCH CONSTRUCTION.

From the fact that considerable capital will be required to divert the waters of the principal rivers of the state from their deep channels, the attempts of the irrigators in the past have been confined almost exclusively to those localities where streams of moderate size flow from the foothills into small open valleys or upon the edge of the larger plains. Here, at favorable points, small ditches have been dug running for a few miles along the river and as far away from it as the contour of the ground will allow. The early settlers generally constructed very small ditches, and as the population in any one locality increased other ditches were made, either higher or lower on the stream, each of these leading to the lands of a few irrigators. As a general rule the ditch last constructed is the largest and best, although, on account of the existence of other older ditches, it may not be well located or have rights to any but surplus water.

Taking the state as a whole, there was in 1889 an independent ditch leading from a river for every 385 acres of crop irrigated, deducting in this, however, a few of the larger canals. It has been shown that in Montana the corresponding area per ditch was 225 acres.

DUTY AND USE OF WATER.

The duty of water has been estimated in many cases by ditch owners, and the statements range from 50 to 250 miner's inches for 100 acres, the average being 120 miner's inches. Assuming that 50 of these miner's inches make a second-foot, this would be equivalent to an average water duty of 42 acres per second-foot. The accuracy of these statements is open to question, from the fact that water measurements are rarely made with any care, if made at all, in obtaining these figures. The miner's inch is exceedingly variable, and it is rare that any two irrigators agree in their opinions as to the methods of measuring it. Thus, since even the unit of measurement is undetermined it is doubtful whether the results expressed in this unit are of value.

The methods of using the water upon the land are as varied as the experience of the persons using it. As a general rule the farmers confess that they have much to learn in this direction, that the majority of the land is not well irrigated, and that the crops are not as large as they should be. In irrigated counties it is possible to pick out many areas on which wonderful crops are raised largely through the exercise of unusual skill and intelligence on the part of the irrigators, and were these instances taken alone the conclusion could be drawn that the farmer employing irrigation was the most successful and prosperous individual of his kind. Unfortunately the rank and file of farmers who have been forced to adopt irrigation have done so almost under protest, and do not in the majority of cases exhibit great skill. Great disparity is to be seen between crops on adjacent farms where all the physical conditions are similar.

The most widespread method of irrigating is to turn the water out upon the field and let it find its own way. This is the lowest stage of development, and from this as one extreme every method can be found in use in Idaho up to the case of the farmer who levels his ground, plowing down the high places, filling depressions, and systematically laying off furrows so that every portion of the field receives only its due share of water. This difference in the preparation of the ground, as well as in the character of the soil and subsoil and the kind of crop, gives rise to the widest range in the duty of water, so that any generalization must be taken as such and not applied to particular cases or localities.

The irrigating season begins in April and continues until September, although some farmers at lower altitudes begin to use the water as early as March, and others, higher in the mountains, as late as June. For the greater number of the irrigators scarcity of water puts an end to irrigation, while those who hold prior rights and can obtain the water use it until frosts set in. The principal irrigated crop is for forage, and of the forage plants the most valuable is lucern, or alfalfa. In general, two crops of this product are cut, and in some cases three or even more, but often on account of the scarcity of water only one crop is successful.

The laws regarding the control of the water and the rights of the different irrigators depending upon any one stream are not satisfactory to the farmers, for they do not appear to guard the rights of individuals. There is a general complaint that no one can enjoy the undisturbed ownership of water sufficient to render his farm productive until his rights have been tested by lawsuits, often of the most expensive and protracted nature. Even then there may be questions of doubt to disturb the value of his lands. Points in the present statutes are stated to react injuriously upon agricultural interests. The situation in many localities is complicated by the rapid growth of new and improved systems of irrigation, the rights of such systems to water being, however, secondary to those of the older, poorly built ditches. Some of these systems are being built by corporations that are investing considerable capital in bringing large areas under ditch and increasing the extent of the agricultural lands.

The feeling of the farmers toward the corporations owning canals and renting the water, or rather charging so much per annum for bringing it to the land, is not always friendly. The water rates are burdensome to the farmers although not necessarily profitable to the canal owners. The farmers complain that in the first instance inducements are held out to them of benefits that are never fully realized. They are persuaded to pay from $8 to $10 per acre for a water right which entitles them to a certain amount of water upon the annual payment of from $1 to $3 an acre for what may be considered the expense of transporting the water to the land. In certain instances the farmers have signed agreements which virtually amount to mortgages upon their land, and upon failure to comply with the conditions the canal company has acquired possession, the farmer perhaps becoming a tenant of the company.

SPRINGS AND WELLS.

The supply of water from springs and wells has considerable local importance. Along the Snake river, especially in Logan county, are some wonderful springs, which gush from the canyon walls and fall into the gorge. This water is probably the drainage of the mountains to the north which has disappeared into the lava plain and traversed the pervious rock layers. Some of the water can be used for irrigation either by conducting it by flumes and canals to lower lying lands or by utilizing the water power to force a portion of the water to higher levels.

Attempts have been made to find artesian water, but with little success. The railroad known as the Oregon Short Line has drilled several deep wells at stations on the lava plain north of the Snake river, and has struck water at various depths and in large quantities, none of which, however, rises to the surface. The wells range from 150 to 425 feet in depth, and water is brought to the surface by suitable pumping machinery. From the fact that water escapes so freely in the large springs along the Snake, it is doubtful whether flowing wells can be obtained on this plain. In the southeastern corner of Idaho are a number of comparatively shallow flowing wells, principally in the vicinity of Oxford, in Bingham county, and of Malad, in Oneida county. Each of these consists simply of a 1.5 or 2 inch pipe driven into the ground to a depth of from 50 to 150 feet, the water flowing up through the pipe to a distance of a foot or more above the surface. These wells are a very great convenience for house and barn use, but being upon low ground, below irrigating ditches, they are of comparatively little importance in agriculture.

In the vicinity of Boise, in Ada county, are a number of artesian wells, some of them discharging hot water. Two of these, put down by the Boise water works to the depth of about 400 feet, are reported to deliver water at a temperature of from 165 to 170 degrees fahrenheit. These wells flow at the rate of about 1.5 second-feet, or 1,000,000 gallons a day. Other wells north of the town discharge cold water suitable for drinking. At Boise barracks a well 120 feet deep yields about 800 gallons per day. Near Moscow, in Latah county, are wells 7 inches in diameter, discharging sufficient water to supply the town. None of this water is used for irrigation, as it is not necessary in that locality.

CONDITION OF IRRIGATION IN EACH COUNTY.

NUMBER OF IRRIGATORS, AREA IRRIGATED, FARMS, AND CROPS IN EACH COUNTY IN IDAHO IN 1889.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.	OWNERS OF FARMS.(a)		IRRIGATORS.		Area of county in acres.	FARM AREA.		Cereals. (Acres.)	Alfalfa. (Acres.)	AREA IRRIGATED.			Average value of products per acre.
				Total number.	Per cent of population.	Per cent of farm owners.	Per cent of population.		Acres.	Per cent improved.			Per cent of area of county.	Per cent of total farm area.	Per cent of land owned by irrigators.	
Total	4,323	217,005	50	6,603	7.82	65.47	5.12	53,945,600	1,302,256	46.56	98,175	31,895	0.40	16.66	26.08	$12.93
Ada	547	38,910	71	580	6.93	94.31	6.54	1,600,000	111,048	50.90	7,655	3,947	2.43	35.05	36.87	15.04
Alturas	104	4,328	42	104	3.96	100.00	3.96	4,288,006	22,083	23.00	520	316	0.10	19.60	19.60	17.01
Bear Lake	387	19,844	51	392	6.47	98.72	6.39	704,000	49,623	42.53	3,962	1,110	2.82	39.99	40.20	10.52
Bingham	837	40,912	49	951	7.01	88.01	6.17	6,720,000	183,041	35.05	9,501	10,584	0.61	22.35	25.10	9.81
Boise	164	7,829	48	308	9.22	53.25	4.91	2,560,000	50,008	39.50	1,563	418	0.31	15.66	28.56	15.20
Cassia	402	19,800	49	416	13.24	96.63	12.79	2,880,000	80,577	41.88	2,977	4,520	0.69	24.57	24.93	10.41
Custer	171	8,570	50	178	8.18	96.07	7.66	2,240,000	42,570	34.56	2,132	645	0.38	20.13	23.09	17.48
Elmore	87	3,437	40	96	5.13	90.63	4.65	1,920,000	18,368	33.73	20	294	0.18	18.71	18.71	11.73
Idaho	36	466	13	487	16.48	7.39	1.22	7,296,000	118,538	59.94	3,001	11	0.01	0.39	8.07	(b)
Kootenai	2	9	5	210	5.11	0.95	0.05	3,584,000	39,483	38.54	933	18	....	0.02	2.80	(b)
Latah	....	....	....	837	9.34	....	....	691,200	170,508	67.76	31,765	21	....	....	....	....
Lemhi	140	9,984	71	148	7.73	94.59	7.31	3,456,000	37,682	44.27	2,272	736	0.29	26.50	26.50	15.89
Logan	316	15,793	50	381	9.14	82.94	7.58	3,712,000	83,893	41.00	1,543	2,086	0.43	18.83	21.08	13.03
Nez Perces	22	482	22	226	7.94	9.73	0.77	1,030,400	71,281	57.84	13,684	3	0.05	0.68	5.27	(b)
Oneida	630	21,423	34	637	9.34	98.90	9.24	1,728,000	94,518	48.62	11,460	4,869	1.24	22.67	23.00	13.15
Owyhee	155	9,076	59	164	8.11	94.51	7.67	4,992,000	42,228	31.57	448	1,539	0.18	21.49	23.74	13.90
Shoshone	....	....	....	40	0.74	....	....	2,816,000	5,833	82.09	220	....	....	....	....	....
Washington	323	16,133	50	428	11.16	75.47	8.42	1,728,000	80,974	36.87	4,519	778	0.93	19.92	25.24	15.59

a Includes owned and hired farms, assuming one farmer to each.

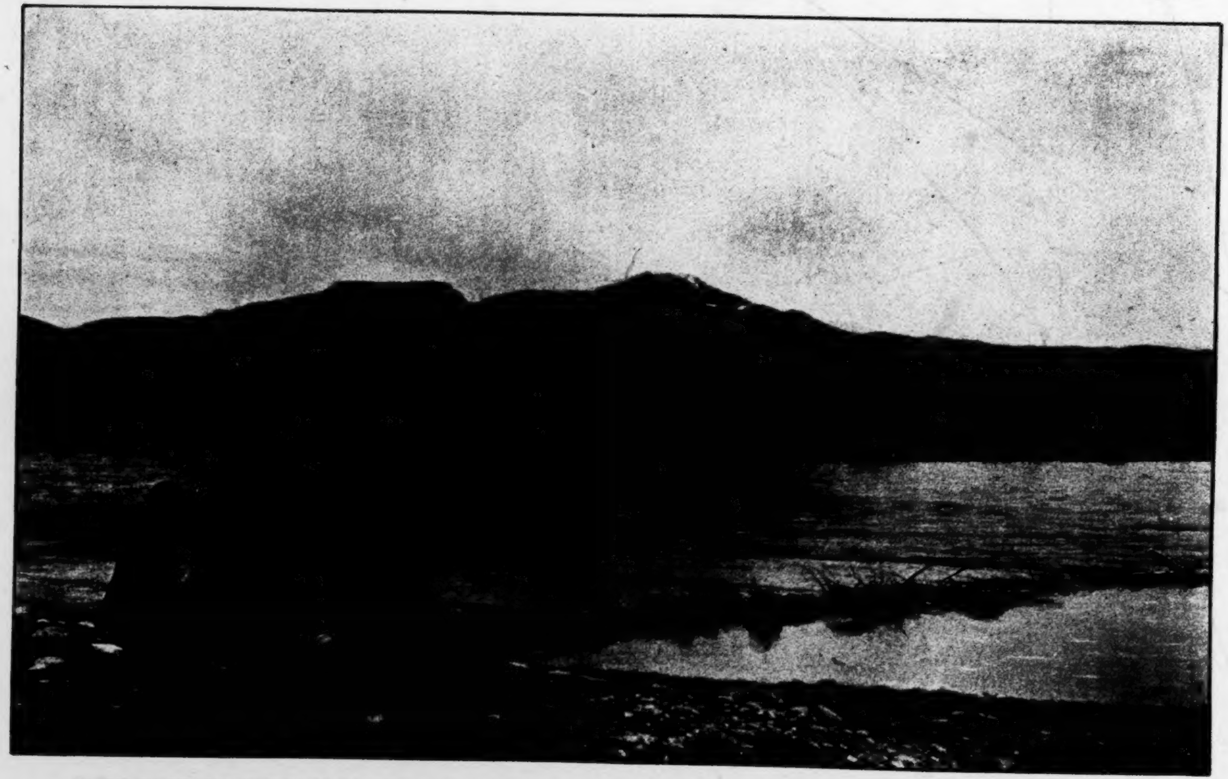
b Not reported.

ADA COUNTY is in southwestern Idaho, on the north and east of the Snake river, covering the comparatively level ground between that river and the mountains. It is crossed by two large streams, the Payette on the north, and the Boise at about the center. Each of these streams carries a large and perennial supply of water, and coming from a mountainous region in Boise and Elmore counties, they are not liable to notable diversion before reaching Ada county. The opportunities for irrigation development in this county are exceptionally good on account of the character of these rivers and the existence of great areas of fertile land to which the water can be brought. Already a number of canals of large size have been built, besides numerous small ditches, and some of the greatest irrigation projects in the country have been begun.

On the lower lands, along the Payette and Boise, crops can sometimes be raised by the moisture which seeps through the ground at the time of flood. The farmers have taken out small ditches from the rivers and perennial creeks, and in this way have brought considerable areas under irrigation at small cost. Following the construction of the individual ditches have come the associations of farmers, who by united effort have built canals from the Payette and Boise rivers, the ownership being largely in the hands of those using the water. In the northern part of the county a large proportion of the arable land can be covered by water from the Payette or the Boise river, but at the southern end the elevation is too great to allow of water being brought from any large sources of supply. The Snake river, which bounds this land on the southwest, flows in a gorge or canyon at such a depth that there is no probability that water can be brought out even by canals heading farther up the river.

Most of the irrigation from the Payette is on the south side of the river, but on the north side is a canal, known as the Lower Payette ditch, taking water from the river about 7 miles above the town of Payette and carrying it for a distance of nearly 22 miles into the Snake River valley, and extending into Washington county. The average width is said to be 20 feet, the average depth 4 feet, and total cost $32,000. On the south side of the river are a number of large ditches, among which may be mentioned the Last Chance, 7 miles long, 8 feet wide on bottom, 1.5 feet deep, the cost of which was $10,000. The head of the ditch is about 30 miles above the mouth of the Payette river. The Rossi ditch also takes water from the south side of the Payette river, heading 4 miles below Emmett. Its total length is 10 miles, its average width 9 feet, and its total cost about $10,000. The ditch is owned by an unincorporated company. Each ranchman under the ditch takes as much water as he chooses when there is plenty and at other times the watermaster regulates the supply.

The largest project along this valley is that of the Payette Valley Irrigation and Water Power Company, diverting water from the south side of the river at a point nearly 2 miles above the town of Emmett. The canal



SCENE ON SOUTH BRANCH OF PAYETTE RIVER AT POINT OF DIVERSION OF THE CANAL OF PAYETTE VALLEY IRRIGATION AND WATER POWER COMPANY, ABOUT TWO MILES ABOVE EMMETT, ADA COUNTY, IDAHO.

at the head has an estimated capacity of 556 second-feet, diminishing to 104 second-feet in the last section. It is the intention of the company to use this canal at certain times of the year in order to float logs down the valley, avoiding the risks incident to their transportation by the river. Along the line of the canal are several flumes, one of which is nearly 3,000 feet in length. Several gulches on the line of the canal have been closed by dams, forming small reservoirs, one of which at least will be utilized for the storage of logs. At a distance of about 7 miles from the head the canal divides, one branch continuing west to cover lands on the Snake river bottom, the other branch, known as the Flotation lateral, extending northerly to the Payette river. Along the canal line are a number of drops at which a considerable power could be developed. The accompanying illustration shows the general character of Payette river and also the temporary brush and stone dam of the usual character for diverting the river water into the head of the canal.

On the north side of the Boise river, among the canals worthy of mention is the Boise City canal, 5 miles long, 8 feet wide, and costing about $12,000. The ownership is divided into 12 shares. There is also the Dry Creek ditch, 6.5 miles long and 9 feet wide, the cost of which was $4,000. It was built and owned by the farmers, each share entitling the owner to a certain proportion of the water. The largest canal on this side of the river is that of the Idaho Irrigation and Colonization Company, heading about 30 miles below Boise city and 1 mile above Caldwell. Its general course is northwesterly in the direction of the Snake river. Its total length is 24 miles, its average width 10 feet, and its cost about $35,000. Besides these are many other ditches, large and small, taking water in the same general direction.

On the south side of Boise river is the Ridenbaugh ditch, owned by the Boise City and Nampa Canal Company, the Settlers canal, and the unfinished works belonging to the Idaho Mining and Irrigation Company, besides smaller ditches farther down stream. The Ridenbaugh ditch has been enlarged and extended in order to cover lands on the mesa from Boise to Nampa. The ditch is stated to be 22 feet wide at bottom and 32 feet wide at top. It is the intention of the company to further enlarge and extend this canal to cover upward of 200,000 acres of land. The high line canal of the Idaho Mining and Irrigation Company has been planned with the purpose of diverting water at a point in the canyon about 12 miles above Boise. A large part of the earthwork has been completed, but owing to financial difficulties the headworks have not been built. The Phillis canal, owned by the same company, although nearly completed, has not been utilized. This has an estimated capacity of 175 second-feet, the bottom width being 20 feet and the length approximating 50 miles.

The Dixie canal of the Boise Land and Water Company utilizes as a portion of its main channel a depression known as Dixie slough. The waters of Boise river are diverted into this at a point about 1.5 miles below Caldwell by means of a cut 500 feet long and 8 feet deep. The water follows along the old slough for about 6 miles, and is there turned into the canal proper by a suitable dam. From this point the main ditch follows the general contour of the land for a distance of 9 miles. It was originally built by farmers, at a cost of $20,000. The company now owning this work intends to improve and extend the line so as to cover the lands in the triangular area between the Snake and Boise rivers, it being proposed to charge at the rate of $10 per acre for a perpetual water right and 50 cents per acre a year for maintenance.

The discharge of the Boise river has been measured by Mr. A. D. Foote, and has been found to range from about 1,200 second-feet in low water up to 10,000 second-feet at the time of the spring floods, the greatest known discharge being about 30,000 second-feet. In order to supply water for all the canals now in operation or projected it will probably be necessary to supplement the low water discharge by storage on the head waters in Boise and Elmore counties, excellent sites for reservoirs having been discovered. The discharge of the Payette is not known, but is probably not very different from that of the Boise, averaging, it is stated, about 3,000 second-feet.

ALTURAS COUNTY is a little south of the center of the state, extending east and west in a long, narrow belt north of the Snake River plains. On the west it includes the head waters of the tributaries of the Wood river, all of which flow southward into Logan county. It also includes on the extreme west a portion of the Sawtooth range, from which streams flow northeast into the Salmon river, and westward into the Boise. The area of agricultural land in this part of the county is comparatively limited, and the water supply is ample, although farther to the south, in Logan county, are vast areas for which the amount flowing from Alturas county is insignificant.

On the east, the county extends to the lava plain of the Snake river, into which sink the rivers which flow from the ranges to the northwest. This fact has given rise to the names of the streams, namely, "Big Lost river" and "Little Lost river". Big Lost river rises in Custer county on the west side of the Lost River range and flows southeasterly into Alturas county, where its waters are used upon ranches along the stream. In time of flood the water flows far out upon the lava plain toward the Snake river. In 1889 it ran to a point 3 miles below Arco, but in the middle of June of the same year it was dry up to the mouth of Antelope creek, 20 miles above Arco. Not only are the channels of the streams very porous, allowing great quantities of water to escape into the lava fields, but the soil also is in many places very pervious, and a large amount of water is needed for irrigation, especially during the first few years.

The water of the tributaries of the Big Lost river is used to a large extent in Thousand Spring valley and other valleys in Custer county, so that the amount which escapes into Alturas county is gradually diminishing. It has been proposed to make an effort to remedy this state of things by constructing reservoirs at points in Custer county, but no active steps have been taken in the matter. Stock raising and mining are the principal industries, the cultivation of the soil being carried on largely in connection with the former. The ditches of the county are owned by individuals or associations of irrigators, and have been built for the most part in the cheapest possible manner. The noria, or undershot water wheel, carrying buckets upon the rim for raising water, has been introduced, and is used upon the swifter streams.

BEAR LAKE COUNTY is in the southeastern corner of Idaho, adjoining Rich county, Utah, on the south, and Uinta county, Wyoming, on the east. It includes that portion of the drainage area of Bear lake which lies in Idaho, being bounded on the west by the summits of the Bear River range, and on the northeast by the Aspen range, which forms the divide between the Blackfoot and Bear rivers. The southern boundary of Idaho, extending east and west, crosses Bear lake near its center, leaving the northern half in Bear Lake county and the southern half in Rich county, Utah. North of the lake is an almost level plain, about 16 miles long and 8 miles wide. A portion of it is swampy, and on the maps of the General Land Office it is represented as an open body of water called the North lake, but on the Hayden map, published in 1877, it is shown as it actually is, namely, a marsh with a small body of open water to the south. In 1889 this marsh was perfectly dry, excepting the small area of water in the southeast corner near the head of Bear lake. Roads cross this level land in all directions, and it is occupied by farmers who have built houses, barns, and fences, and are raising large crops of hay. No title, however, could be secured from the government on account of the official designation of the land as a lake.

The upper Bear river, rising in Summit county, Utah, first flows into Wyoming, then westward into Rich county, Utah, then back into Wyoming, and finally, turning westward again around the northern end of the boundary hills and the Bear Lake plateau, it enters the eastern side of the plain north of Bear lake, where its waters divide into many channels. At the northern end of this plain the lower Bear river takes its origin, winding northerly between hills to the vicinity of Soda Springs, in Bingham county, where it is deflected and turned southward toward Cache valley.

The water from the upper Bear river in times of flood partially submerges the plain and backs up into Bear lake, and in times of drought the waters of Bear lake, escaping through marshy channels, traverse the level country and finally make their way into the lower Bear river. Thus the lake and low lands to the north act somewhat as a safety valve to the floods of the upper river, receiving them and slowly delivering them, at least in part, to the lower section of the drainage system. To represent the condition of affairs clearly, it will be well to picture a long, narrow lake basin, 35 miles or more in extent from north to south, and about 8 miles in average width. Into this a river has flowed for long periods of time, entering near the northern end and gradually building a delta and filling the upper half of the basin with débris brought down in floods. In this way a level plain of great fertility has been formed at the northern end of the old lake basin, and at the same time the open water at the south end of the basin has, under the influence of prevailing winds, built for itself a barrier 4 miles or more in length and lying nearly east and west. The barrier consists of a ridge of sand from 100 to 200 feet in width, and from 4 to 6 feet above the ordinary level of the water. Toward the lake the barrier presents a smooth and beautiful beach, and on the north it gradually subsides into the marsh.

The future development of agriculture along the lower Bear river depends largely upon the control of this magnificent reservoir site, and at the same time the prosperity of a large part of Bear Lake county is at stake. The problem before the people of the Bear River drainage, whether in Wyoming or in Utah, is so to utilize Bear lake as a reservoir that a supply of water shall be insured ample for all demands along the lower Bear, and also that all of the agricultural land of Bear Lake county shall be utilized. Without entering upon the engineering details it is sufficient to state that the best use of the waters can probably be secured by the construction of an outlet canal to lower the level of Bear lake in times of need, suitable headworks being provided, so that the water can be held up to its present area. By diverting the upper Bear river directly into Bear lake and by drawing the waters down to the lowest possible level, a vast amount of water can be secured for use upon the lands in the lower valleys. The satisfactory execution of works will, however, require large capital, skillful engineering, as well as hearty co-operation between the people of Idaho and those of Utah.

The agricultural areas of Bear Lake county are principally along the eastern foot of the Bear River range, stretching in a comparatively narrow strip between the mountains and the lake, or extending from the hills out upon the plain to the north of the lake. A number of streams flow from this range with rapid fall, so that water has been taken out upon the land with comparative ease. A town has grown up at each point where a large stream issues from the mountains, the population being almost wholly supported by agriculture or stock raising. The creek near Paris discharges in summer about 40 second-feet, running a flour mill and sawmill. St. Charles creek on October 3, 1889, was flowing at the rate of from 90 to 100 second-feet, and also furnished power for a flour mill besides irrigating a considerable area.

The east side of Bear Lake valley is in most respects similar to the west side, although the mountains being, as a general rule, of less height, the water supply is smaller and the number of agricultural settlements less. East of this valley, on the other side of the Preuss range, is the valley of Thomas Fork, the greater part of which is in this county, the state line between Idaho and Wyoming running north and south along the valley. There is a large area of fertile land along Thomas Fork, but the water supply is deficient, and an attempt has been made to bring water from Smith Fork, farther to the east.

The altitude of the agricultural lands of Bear Lake county is very nearly 6,000 feet. The climate is cool, and frosts are liable to occur even during the summer, so that some of the farmers state that oats and timothy are the only sure crops. The principal crops are for forage, although large areas of the smaller grains are cultivated, and also some potatoes and vegetables. Stock raising is the leading industry, on account of the excellent summer feed upon the mountains and the facilities for raising hay for feed during the winter. Most of the inhabitants came originally from Utah, so that the methods of irrigation are similar to those employed in that territory. The water from each mountain stream is taken by ditches which head in or near the canyons and conduct it along the slopes of the hills on each side of the stream. Generally, two, but sometimes three or even more ditches run in a course nearly parallel to each other, carrying the water in the same direction, but with less economy than could be attained by the use of one large high line canal. The advantages, however, of a number of small ditches are that each small association of farmers controls the water for a particular district and the management is greatly simplified, although, on the other hand, quarrels are apt to arise in time of low water as to the proportional amount to be taken from the stream.

At this high altitude water must be used with care, for if put upon the plants too early in the spring it chills them and retards their growth. It is stated that an error is often made in attributing the slow growth of the young plants in the cool spring to lack of water rather than to lack of warmth, and thus irrigation is begun too early with injurious results. The amount of water used is very great, especially on the gravelly slopes, where the ground is porous. It is asserted that 100 miner's inches for 40 acres are sometimes necessary to satisfy the demands of the irrigator.

As an example of the ditch systems of this county, that for Bloomington, on the west side of the valley, may be given. Four ditches take the water from Bloomington Canyon creek, the length being about 4 miles, their average width 5 feet, their depth 2 feet, and their total cost about $8,000. The water is diverted by dams of brush and stone or of logs. The water is divided among the shareholders, each share entitling the holder to what is known as an "irrigating stream" for 48 hours, during which time he is supposed to be able to irrigate 5 acres. The water is measured, as in many cases in Utah, by the size of the cross section of the stream when not under pressure, no account, therefore, being taken of the velocity. For example, the water flowing 10 inches deep through a gate or flume 50 inches wide is considered to have a volume of 500 inches, and should give 10 "irrigating streams". It is customary to allow the use of one of these "streams" for 96 hours for every 10 acres. The streams are allotted in the order of application until the whole amount of water has been assigned, and the various applicants are then notified as to who is using the water and when each irrigator may expect to take his turn. The water right is stated to be worth $5 per acre, and the annual assessment for cleaning the ditch and paying the watermaster is from 30 to 40 cents per acre. Of this amount 15 cents must be in cash for the pay of the watermaster, and the balance can be worked out at the rate of $1.50 per day. In the case of another ditch the "irrigating stream" is measured through a box 1 foot square under a 4-inch pressure, this amount of water being allotted at the rate of 35 hours for every 10 acres.

In general it may be said that the water is under the control of the irrigators, who have built the ditches and have adopted methods of distribution which, although crude, are efficient so long as water is plentiful. It is the practice for each association controlling a ditch to elect annually a watermaster, who receives $1.50 a day and upward for his services, and who apportions the water and settles disputes among neighboring irrigators according to his own judgment. The total cost of maintaining the ditch system is thus very low, as there are no salaries or expenditures beyond those for a few simple repairs.

BINGHAM COUNTY is in southeastern Idaho, adjoining Wyoming and the Yellowstone national park on the east, and separated from Montana by the continental divide on the north. It receives the drainage of the high mountain ranges of western Wyoming, and has probably as good a water supply as any county in the arid region, and it is favored not only in this respect but also in containing vast areas of almost level land, the surface of which, though broken in places, is well adapted for agriculture. The county contained in 1890 the largest number of irrigated farms.

The agricultural resources of the county are due to its peculiar history. In comparatively recent geologic time, as previously intimated, a vast quantity of lava flowed from numerous craters or openings, filled ancient valleys, and extended from the foot of the continental divide and of the Teton and Caribou ranges south and west for 100 miles or more. The surface of this lava sheet is as a whole gently inclined toward the southwest, and though appearing at a distance smooth and unbroken is often uneven. The upper layer has been partially decomposed, forming in places a rich soil, which, however, is very porous. The torrential streams flowing from the high mountains out upon this plain become comparatively sluggish, subdividing in places, but finally uniting and forming the Snake river in the vicinity of Market Lake. Near the intersection of the principal streams large areas of fertile land have been formed by the deposition of material brought down by the torrents, the relative elevation of the land and the water being such that irrigating ditches can be easily and cheaply constructed.

In the northwestern part of the county, north of the tilled lands at the junction of the north and south forks of the Snake, the extensive lava plains have little or no water, for the streams that flow southward from the continental divide are comparatively small and often are lost in the porous lava fields. There are accordingly many townships containing arable land for which there appears to be no possible way of obtaining water. At the southern end of this county the lava has penetrated the ancient valleys and extends to the Bear river, which enters the county from Bear Lake county on the southeast. Apparently this latter river has been diverted by the lava flow, and soon after entering the county has been forced to turn back toward the south, ultimately contributing its waters to Great Salt lake. The principal body of tilled land, as before intimated, is along the lower courses of the rivers which issue from the Teton and Snake River ranges and unites in the vicinity of Market Lake, the farms extending from this point down to Blackfoot. Besides this great area, there are smaller areas of crops raised along the Bear river from Soda Springs to the Oneida county line, principally in Gentile valley and also along the Portneuf river, in the upper Portneuf valley on the head waters of Marsh creek, as well as on small areas on the Fort Hall Indian reservation.

Gentile valley is about 15 miles long and from 1 mile to 3 miles in width. There are few towns, the farms being scattered along the sides of the valley, utilizing the water from the streams which issue from the mountains on the east and west. Bear river, which flows southward through the valley, although a large stream, is not used to a notable extent on account of the difficulty of diverting water. The best irrigating streams are those coming from the Bear River range on the east, the water supply of the west side of the valley being insufficient for the area now under cultivation. The most important streams are Trout, Spring, and Bridge creeks, coming from Bear River range on the east. Cottonwood creek, which drains a larger area of lower country, is of less value, not having sufficient water for all of the land to which it can be taken.

In the extreme southern part of the county in the vicinity of Oxford and Swan lake are prosperous settlements, the water supply being derived from streams which flow from the Portneuf or from the Malade range. Some of these streams flow northward into the Portneuf river, a tributary of the Snake, and thus ultimately to the Pacific, while others find their way to Bear river, the principal feeder of Great Salt lake. The long, narrow valley in this vicinity once formed the outlet of the great interior basin to which the term Lake Bonneville has been given, and many of the peculiar features upon which its agricultural development depends are explained by this knowledge of its past history. At several points in this valley near Oxford small flowing wells are found. The present supply from the small streams is not sufficient for all demands, and schemes for storage are being agitated, several small reservoirs built by individuals having established the success of such methods.

North of this point, in the vicinity of Chesterfield, in the Upper Portneuf valley, is an agricultural community of from 50 to 60 families. Their cultivated land lies just east of the Fort Hall Indian reservation, out of which the head waters of the Upper Portneuf flow in a general southeasterly direction. The location of the Indian reservation across the head waters of the Portneuf has led to a somewhat unfortunate condition of affairs for the farmers in this valley. Nearly 6 years ago they constructed a ditch, 4 miles of the upper part of which were on the Indian reservation, and spent upward of $3,500. Objections, however, were raised to the location of the ditch on the reservation, and as a consequence it has lain idle. The water supply is now taken from creeks heading to the east of the reservation, the amount available, however, being far below the requirements of the people, so that it is stated that only about 10 or 15 acres, on an average, can be cultivated by each family. An attempt is being made to increase the water supply by storage. Farther down the Portneuf, in the vicinity of Pocatello, are lands of great fertility, but for which the water supply of the Portneuf is insufficient. A large portion, however, will be covered in time by large canals taken out farther up on the Snake river near Idaho Falls and brought along the eastern side of the plain.

The Blackfoot river heads in the range of the same name immediately north of the Portneuf and flows westward upon the lava plain to join the Snake river. Its waters in time of drought are entirely used, and in 1889 there was not enough for the needs of the town of Blackfoot. The Eastern Idaho Water Company has a canal heading about 12 miles northeast of this town and continuing to Blackfoot, the average width being reported to be 20 feet, and the total cost nearly $8,000. The Indian reservation is bounded on the north by the Blackfoot river, and some trouble is reported between the irrigators and the Indians, who are said to have destroyed the ends of the dams which reached their lands on the south bank of the river.

At the head of each of the streams flowing out of the short mountain ranges of this county to the Snake river are lakes or marshes, in which it is probable that considerable water could be held by storage, but the proximity of the Snake river and the magnificent facilities for water conservation which exist on its headwaters cause them to sink into insignificance. Taking all things into consideration, the Snake is the largest river in the arid lands, exceeding even the Yellowstone and the Missouri, and containing along its valley perhaps the greatest body of irrigable land in the west. The extraordinary facilities it affords have already been used in a small way, but the greater projects remain untouched. From Henry fork of the Snake, from Falls and Teton rivers, Moody creek, and the south fork of the Snake, a large number of ditches and canals carry water out upon the lava formed plain, intermingling in a most confusing manner. The soil of the deltas or islands at the junction of these streams is very rich, and agriculture has made rapid progress, all of the conditions being favorable to rapid development by men of small means. The altitude of the valley in the vicinity of Eagle Rock, or Idaho Falls, as it is now called, is from 4,800 to 5,000 feet.

In 1889 there was no irrigation carried on in the mountain valleys of these streams above the Snake River plains, the settlers on the plains below coming up to cut the natural hay for use during the winter. Above the mouth of Falls river the country was unsettled, and on Falls river the first steps were being taken toward irrigation by the construction of two ditches, no land having been brought under cultivation. Since that time, however, rapid growth has taken place, and settlement has pushed forward actively. In the Teton River valley it may be said that all of the water of the Teton river has been appropriated, and there is land not yet supplied. Water is being brought from Falls river around the foothills into the Teton valley, the divide being comparatively low.

The water supply of this part of Idaho has been investigated by the United States Geological Survey, and measurements have been made of the discharge of the streams at various points, for example, of Henry fork of the Snake river about a mile above Falls river, also of Falls river above the canals and 6 miles from the junction with Henry fork, of the Teton river above the Willford canal near the mouth of the canyon, of the south fork of the Snake above the Eagle Rock and Willow Creek canal, and of the Snake river at Idaho Falls. (*a*)

---

[a] As shown by the following tables, the maximum discharge of Henry fork was up to June, 1891, 7,710 second-feet, the minimum being 1,120 second-feet, and the average annual discharge 1,589 second-feet, equivalent to 1,150,071 acre-feet for the entire year. The drainage area is approximately 931 square miles, so that this water if put back upon the catchment area would cover it to the depth of 23.2 inches. These observations extending over a period of 18 months, it would be unfair to take the direct mean of that period, since the flood season occurs twice, and this would tend to raise the mean, hence this statement is arbitrary, showing the approximate annual discharge.

Falls river discharged a maximum of 4,440 second-feet, a minimum of 450, an estimated average of 1,041, an amount equivalent to 753,684 acre-feet for the year. This is equivalent to a depth of 23.7 inches over the catchment area. The Teton discharged a volume of water ranging from 4,445 second-feet in flood down to 490 second-feet in time of low water, and averaging 862 second-feet, or for the entire year 624,450 acre-feet, equivalent to a run-off of 12.1 inches for the entire basin

The total discharge of the Snake river, as measured at Idaho Falls, during 1890 ranged from 50,450 second-feet in time of flood down to 2,000 in low water, the average being estimated at 9,486 second-feet, or 6,867,140 acre-feet, equivalent to a run-off of 12.7 inches from the entire drainage basin.

DISCHARGE OF HENRY FORK IN CANYON, IDAHO.

(Drainage area, 931 square miles.)

Months.	Discharge in second-feet.			Total for month in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1890.						
January	....	....	1,200	73,800	1.49	1.29
February	....	....	1,250	69,375	1.40	1.35
March	....	....	1,300	79,950	1.61	1.40
April 6 to 30	4,920	1,120	1,875	111,562	2.25	2.01
May	7,710	2,750	4,580	281,670	5.67	4.92
June	2,890	1,800	2,270	135,065	2.72	2.44
July	1,860	1,450	1,550	95,325	1.92	1.66
August	1,450	1,450	1,450	89,175	1.80	1.56
September	1,450	1,280	1,314	78,183	1.57	1.41
October	1,280	1,280	1,280	78,720	1.59	1.38
November	1,280	1,280	1,280	76,160	1.55	1.37
December	1,280	1,280	1,280	78,720	1.59	1.38
Per annum	7,710	1,120	1,719	1,247,705	25.16	1.85
1891.						
January	1,280	1,280	1,280	78,720	1.59	1.38
February	1,280	1,280	1,280	71,040	1.43	1.38
March	1,280	1,280	1,280	78,720	1.59	1.38
April	2,600	1,280	1,516	90,505	1.83	1.63
May	3,180	1,640	2,184	134,216	2.71	2.33
June	2,215	1,450	1,801	107,160	2.16	1.94

DISCHARGE OF FALLS RIVER IN CANYON, IDAHO.

(Drainage area, 594 square miles.)

Months.	Discharge in second-feet.			Total for month in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1890.						
April 25 to 30	2,480	1,250	1,730	102,935	3.25	2.93
May	4,440	2,630	3,342	205,533	6.49	5.63
June	4,050	2,030	2,706	161,007	5.08	4.56
July	2,630	1,030	1,669	102,643	3.20	2.81
August	1,140	840	971	59,717	1.82	1.63
September	930	660	774	46,053	1.45	1.30
October	750	570	660	40,590	1.26	1.09
November	570	490	541	32,189	0.95	0.86
December	520	520	520	31,980	0.93	0.81
1891.						
January	590	450	503	31,304	0.99	0.86
February	....	....	450	24,975	0.79	0.76
March	....	....	450	27,675	0.87	0.76
April	1,140	450	606	36,057	1.14	1.02
May	2,790	1,030	1,765	108,547	3.43	2.98
June	2,180	1,370	1,681	100,019	3.17	2.85
July	1,760	670	1,131	69,556	2.20	1.91
August	670	520	607	37,330	1.18	1.02
September	520	520	520	30,940	0.96	0.88
October	520	520	520	31,980	1.01	0.88
November	520	520	520	30,940	0.96	0.88
December 1 to 12	520	520	520	31,980	1.01	0.88
Per annum	2,790	450	773	561,303	17.75	1.31

Without attempting to describe in detail the irrigating systems which extend from Falls river to below Idaho Falls, it will be sufficient to mention a few of the more prominent ditches, the location of which is shown on the map. On the west side of Henry fork the St. Anthony canal is reported to be about 21 miles in length and 28 feet wide. It is owned by a stock company, each share entitling the owner to 10 miner's inches of water. The Egin canal, which is below the St. Anthony canal and in general parallel with it, is about 14 miles long and 25 feet wide, and is said to have cost about $20,000. The ownership is divided into 400 shares, each share entitling the holder to a proportionate amount of water.

The largest ditches are those taken from the south fork of the Snake, covering the land in the vicinity and north of Idaho Falls. For instance, the Eagle Rock and Willow Creek Water Company has a canal 25 miles long and 30 feet wide, with an average depth of about 3 feet. The cost is said to have been $100,000. Each share in this company entitles the owner to 5 inches of water, 1 inch being considered under ordinary circumstances sufficient for 1 acre of land. The Farmers Friend ditch is 5 miles long and 20 feet wide. It cost $11,000, and covers land below the canal just mentioned, being built by irrigators. In the vicinity of Idaho Falls are two large canals, the Great Western and the Idaho, heading on opposite sides of the river near Bear island. The latter of these is reported to be 40 feet wide and 4 feet deep, and at a distance of 12 miles from the head to be 20 feet wide.

The country has but recently been settled, and as yet the farms are hardly in good order, as is shown by the average value of products. Ditches are being built and enlarged constantly, some running parallel and others crossing from point to point. In general the irrigation systems are owned by the farmers, although a few are in the hands of corporations. A good example is here afforded of the growth which takes place without system or

DISCHARGE OF TETON RIVER AT CHASES RANCH, IDAHO.

(Drainage area, 967 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1890.						
April 5 to 30	1,295	545	740	44,030	0.85	0.77
May	4,445	1,545	2,739	167,895	3.28	2.82
June	4,065	1,925	2,812	167,314	3.26	2.91
July	2,950	935	2,130	130,995	2.51	2.20
August	935	510	678	41,697	0.81	0.70
September	510	450	462	27,489	0.53	0.48
October	510	450	475	29,212	0.57	0.49
November	450	450	450	26,775	0.52	0.46
December	510	450	459	28,228	0.55	0.47
1891.						
January			400	24,600	0.48	0.41
February 17 to 28	475	450	465	25,807	0.50	0.48
March	450	450	450	27,675	0.54	0.47
April	935	450	630	37,485	0.72	0.65
May	2,360	720	1,402	86,223	1.66	1.45
June	2,360	1,295	1,661	98,820	1.91	1.72
July	1,635	670	1,050	64.575	1.25	1.09
August	670	450	547	33,640	0.65	0.57
September	450	450	450	26,775	0.52	0.47
October	450	425	444	27,306	0.53	0.46
November			425	25,287	0.49	0.44
December			425	26,137	0.51	0.44
Per annum	2,360	400	696	504,339	9.76	0.72
1892.						
January			400	24,600	0.48	0.41
February			425	24,437	0.47	0.44
March	450	450	450	27,675	0.54	0.47
April	820	450	575	34,212	0.66	0.60
May	4,900	565	1.911	117,526	2.28	1.92
June	5,270	2,245	3,845	228,777	4.43	4.00
July	4,575	1,545	2,780	170,970	3.32	2.68
August	1,456	545	758	46,617	0.90	0.79
September	510	475	488	29,036	0.56	0.51
October	475	450	471	28,965	0.56	0.49
November	450	450	450	26,775	0.52	0.47
December			450	27,675	0.54	0.47
Per annum	5,270	400	1,084	787,265	15.28	1.12

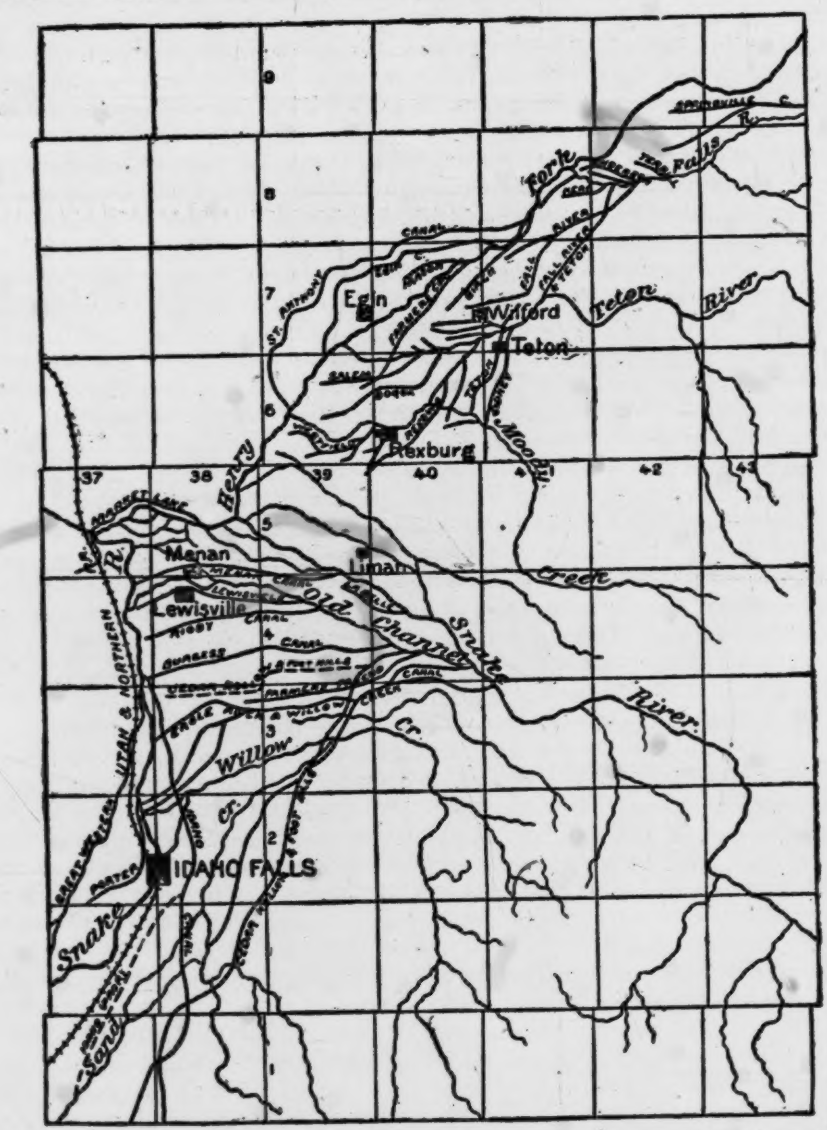
DISCHARGE OF SNAKE RIVER AT IDAHO FALLS, IDAHO.

(Drainage area, 10,100 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
July	8,646	3,174	5,184	318,816	0.59	0.51
August	3,130	2,288	2,596	159,654	0.30	0.26
September	2,508	2,266	2,300	136,850	0.25	0.23
October	2,730	2,286	2,425	149,137	0.28	0.24
November	2,352	2,508	2,737	162,851	0.30	0.27
December	2,730	2,508	2,601	159,961	0.30	0.26
1890.						
January			2,000	123,000	0.23	0.20
February			2,000	111,000	0.21	0.20
March			2,000	123,000	0.23	0.20
April	15,000	2,900	5,702	339,209	0.63	0.57
May	49,350	16,900	35,606	2,189,769	4.06	3.52
June	50,450	24,930	34,870	2,074,765	3.85	3.45
July	28,800	10,700	19,970	1,228,155	2.28	1.98
August	10,350	6,250	7,875	484,312	0.90	0.79
September	5,950	4,350	4,934	293,573	0.54	0.48
October	4,600	4,350	4,552	279,948	0.52	0.45
November	4,350	3,900	4,207	250,316	0.47	0.42
December			3,900	239,850	0.45	0.39
Per annum	50,450	2,000	10,365	7,736,957	14.37	1.05
1891.						
December	2,900	2,550	2,773	170,539	0.32	0.28
1892.						
January			3,000	184,500	0.34	0.30
February			3,000	172,500	0.32	0.30
March 24 to 31	4,100	3,500	3,900	239,850	0.44	0.39
April	4,600	2,250	3,760	223,720	0.41	0.38
May	51,000	4,725	18,187	1,118,500	2.08	1.80
June	54,300	29,675	41,357	2,400,741	4.56	4.10
July	51,000	10,000	24,069	1,480,243	2.75	2.40
August	9,650	4,850	6,463	397,474	0.74	0.64
September	4,850	3,900	4,312	256,546	0.46	0.43
October	4,350	4,100	4,156	255,594	0.47	0.41
November	4,100	4,100	4,100	243,950	0.45	0.41
December			4,000	246,000	0.46	0.40
Per annum	54,300	2,250	10,025	7,279,618	13.50	1.00

comprehensive plan. Fortunately, however, the water supply is large, and the evils resulting from haphazard construction are not apparent.

MAP OF IRRIGATING CANALS IN THE VICINITY OF IDAHO FALLS, BINGHAM COUNTY, IDAHO.


9
8
7
6
5
4
3
2
1
37
38
39
40
41
42
43
Fork
Falls
R.
C.
CANAL
ST. ANTHONY
EGIN C.
FARMERS
FALL RIVER
FALL RIVER & TETON
Egin
Wilford
Teton
Teton River
SALEM
Rexburg
Henry
Moody
Menan
Liman
Creek
MARKET LAKE
R.
Lewisville
Old Channel
Snake
River
LEWISVILLE
RIGBY
CANAL
BURGESS
CANAL
FARMERS FRIEND
CANAL
EAGLE ROCK & WILLOW CREEK
Willow
Cr.
Cr.
UTAH & NORTHERN
GREAT WESTERN
PORTER
IDAHO FALLS
CANAL
Snake
Sand

Several of the canals are so located that they can be enlarged to cover much of the agricultural land to the south of Idaho Falls, but it is probable that to obtain ample water for any great system it will be more advantageous to take water from the main stream near Idaho Falls, instead of from the old channel or sloughs of the south fork. In order to give an idea of the water supply in the south fork of the Snake and also of the diversions being made, the results of a series of gaugings are given. On September 14, 1889, the Eagle Rock and Willow Creek canal was carrying 103 second-feet, the Farmers Friend canal 65 second-feet, Burgess canal 38 second-feet, and on September 16 the Lewisville canal was carrying 74 second-feet, the Old Channel 70 second-feet, La Belle 14 second-feet, Menan canal 236 second feet, and the south fork below these canals 874 second-feet. On September 19 the south fork at the United States Geological Survey gauging station above these canals was carrying 1,614 second-feet.

The ditches from the various streams, especially from the south fork of the Snake, have, as a rule, no permanent headworks, some of them taking water from side channels or sloughs. The expense of construction is relatively small, and most, if not all, of the work can be done by the irrigators. The canals heading on the main river, however, require considerable attention and expense in order to keep the headworks clear. The gravelly bed of the river channel shifts rapidly, and occasionally is scoured out so deep that it is impossible to bring water into the old headworks.

BOISE COUNTY is west of the center of Idaho, and includes the greater part of the catchment area of the Payette river. On the south it extends over the divide to the north fork of the Boise, thus including a small portion of this drainage. It has been mainly a mining county, a number of placers along the Payette having in past years been worked with success. Stock raising is an important industry, the valleys and lower mountains furnishing an excellent range.

The agricultural land lies along the Payette and its tributaries in the southern part of the county, and also on the north fork of the Payette in Long valley at the northern extremity of the county. Long valley lies in a north and south direction, being about 35 miles in length and from 6 to 8 in width. The altitude is from 4,000 to 4,500 feet, and the climate is so cold that until within a few years there has been a belief that no crops could be raised and that the land was suitable only for grazing. Of late years, however, settlers have pushed rapidly into the valley, and they have found that wheat, oats, and barley, and also potatoes and other vegetables could be raised, and that these often succeeded without irrigation. By the use of water artifically applied, however, the land is made to yield larger crops, but in the case of the small grains it is stated that by irrigation the growth is increased and often prolonged so late in the season that they do not mature before winter. At the northern end of the valley are the Payette lakes, in which the river rises, and which might possibly be used for water storage should occasion demand.

Farther down the Payette at Garden valley, and on Jerusalem creek and Squaw creek are small irrigated areas. At these points also barley and wheat are raised to some extent without irrigation, although all crops do better with artificial application of water. In the drought of 1889 the supply of water from the small streams became very scanty, and in a few instances irrigators were compelled to buy water from the miners in order to save their trees and vegetables, the rate given in one instance being 10 cents per miner's inch per day.

Irrigation is being gradually developed in this county, but the ditches are small and take water from creeks and streams as they issue from the sides of the valleys. The Payette is a river of considerable size, but its waters have not been diverted in this county on account of the expense. There is a demand for the construction of canals to cover the great areas in Long valley and in the lower part of the county. The present inhabitants, however, are mostly poor and were barely able to build the small ditches now in use. There is at present an ample supply of water, but the time is not far distant when the entire quantity flowing through the summer in all the streams except the main Payette river will be appropriated.

CASSIA COUNTY is in southern Idaho, adjoining Boxelder county, Utah, and Elko county, Nevada, from whose mountains and plateaus this county receives a large part of its water. Snake river forms the northern boundary, and the tributary streams coming from the south flow nearly due north across the county, passing through many beautiful valleys on their way. Agriculture has been gradually developed wherever water could be obtained for irrigation, and every spring and stream is utilized. The mountains from which the water comes, although rugged in places and including peaks upwards of 10,000 feet in height, are not sufficiently extensive to receive the enormous deposits of snow required to maintain large perennial streams, and for this reason most of the creeks after emerging from the valleys dwindle in the summer to proportions far below the needs of the irrigators. As an example, it has been found that the water in Goose creek falls below 300 miner's inches, as there measured, while the claim of a single irrigator owning prior rights is for 320 inches.

Water is measured usually in a short flume, or box, 16.5 feet long with a total fall of three-eighths of an inch. These boxes may be made of any width desired, but the water must be maintained at a depth of 9 inches. The number of miner's inches is obtained by multiplying the width of the box in inches by 9. It is somewhat difficult to maintain the slope of these boxes constant, and since there are many other varying details, the amount of water carried by the different boxes as an "inch" varies widely. The actual amount of water contained in the average "inch" has not been ascertained. It is stated that water has been decreed by the courts at the rate of 160 of these inches for 160 acres, but several of the irrigators assert that 100 inches should irrigate from 160 to 200 acres.

As a result of gradual settlement and corresponding increase of area under cultivation, the demand for water has grown so that great difficulty is experienced by the older settlers in securing the amount claimed by them. Judicial decisions are usually unsatisfactory, from the fact that although the water may be decreed to certain irrigators, the stream does not furnish a quantity sufficient for these decrees to be enforced. Litigation is pending among many of the irrigators, and prospects of speedy settlement are not encouraging. On nearly every creek are places which the irrigators consider suitable for reservoir sites, but few steps have been taken toward water storage. One or two small reservoirs have been constructed, and the outlet of a lake has been provided with regulating gates so that water can be held. The great demand, however, is for a canal to take water from the Snake river, and it is asserted that such a scheme is practicable, although the surveys of the United States Geological Survey seem to leave the matter in doubt. A line was run from the American falls on Snake river with the object of demonstrating the possibility of bringing the water of the Snake into the valleys of Raft river and Goose creek, but after progressing 13 miles the line was abandoned as impracticable on account of the difficulties of constructing the canal. A higher line was then taken up, with the assumption that water could be taken from a large canal heading near Idaho Falls, but after running 17 miles this survey was also abandoned for the same reason.

Nothing can be raised in this county without irrigation, excepting, perhaps, one crop of alfalfa in the early part of the year, and this would be greatly improved by irrigation. Farming is conducted on a small scale on account of the general scarcity of water, the area prepared by the farmers each year depending somewhat upon the appearance of snow among the high peaks. On many of the main ditches the proportion to be turned to each irrigator is determined by an order of court, but even this is not satisfactory. The general complaint is voiced by one of the irrigators, when he says: "The greatest objection to irrigation is the everlasting litigation prevalent on all streams where there are numerous claimants to water, and the losses to crops from failure of water owing to the very crude law providing for its distribution".

CUSTER COUNTY is nearly in the center of the state, and includes an area of high mountains on the head waters of the main Salmon river. On the southeast it extends into the catchment basins of the Big and Little Lost rivers, and on the northeast it includes that part of the Pahsimeroi valley which lies on the left bank of the stream. It is a mining and stock raising county, but there are three valleys in which agriculture has gained a foothold. Nothing can be raised without irrigation, excepting perhaps on the low natural meadows or in the little valleys high among the mountains. The Salmon river flows north through Round valley, carrying usually a larger quantity of water than is needed, the average amount being given as approximately 600 second-feet. Many ditches are built to take water from this river and also from the tributary streams, and appprently there is an ample supply for all. There are also a number of farms in the valley of the Big Lost river, which flows southeasterly out upon the lava plains of the Snake, and there disappears. The soil in this valley is very porous; great quantities of water are necessary in order to raise a crop, and the supply is not sufficient to meet the demands in this county and also those in Alturas county, farther down the river.

In the Pahsimeroi valley is a large amount of fertile land which can be brought under irrigation. It is only recently that the cultivation of the soil has been attempted by more than a few individuals, as the cattlemen have used this as a range and have opposed the advance of settlers. There is every reason to believe that climate, soil, and water supply are equal to those of the adjacent valleys. In the case of all these agricultural lands there is great need of the construction of a few large, well built canals to receive the waters of the streams before they are lost into the permeable valley bottoms and to conduct them with the least possible loss to the agricultural lands on which they can be used to best advantage. Many of the creeks rapidly diminish in volume after June 15, and the complete development of agriculture is dependent upon the conservation of flood waters for use in the latter part of June and in July.

ELMORE COUNTY is in the southwestern part of Idaho, extending from the north fork of the Boise river south to the Snake river, and bounded on the east and west by straight lines arbitrarily located. This strip of country includes part of three minor drainage basins, these being, first, on the north a large portion of the catchment area of Boise river; second, near the center of the county a small portion of the head waters of Camas creek, which flows easterly into Logan county, opposite to the general course of the Boise; and, third, on the south areas drained by small creeks flowing toward the Snake over or through the lava formed plain bordering that river. The divide between the drainage basin of the Boise and that of the streams to the south is comparatively low, so that these latter streams do not as a rule receive a large or perennial supply of water.

On the northeastern corner of the county is a part of the Sawtooth range, containing summits which rise to heights of 7,000 feet and upward. The water supply of the Boise is therefore large, but the area of tillable land along the river in this county is limited. To the west, however, in Ada county, as previously described, are immense tracts of fertile land requiring all the water which can be furnished by this stream. On the narrow bottom lands in Elmore county are a number of ranches, the average area of the level land of which is from 50 to 100 acres. There still remain other small patches to be taken up by settlers along the mountain valleys, the altitude of these, however, being so great that only forage crops or the hardier grains and vegetables can be successfully raised.

The principal agricultural settlements of the county are along the southern foot of the low range which separates the Snake River plain from the Boise drainage. Along each of the small creeks which issue from these mountains are areas of cultivated land, the water supply without storage being hardly sufficient to cover the land now tilled. Wherever water can be had large crops of wild hay, alfalfa, wheat, rye, and vegetables are raised. There are no canals in this county, irrigation being carried on by means of small private ditches. The inhabitants are hopeful, however, that in the future a great canal may be built to take water from the Snake river far to the east and bring it out upon the broad plain which stretches from the foothills to the edge of the gorge in which the Snake river flows.

The broad, fertile plain extending from the Snake river northward to the foothills is underlaid by lava, and as the streams leave the mountains and flow out upon this lava sheet many of them lose a large part, if not all, of the water into the porous strata, so that on the open ground at a distance from the mountains the water supply is usually more uncertain and less in quantity than it is in the narrow valleys. Among the foothills there is usually an ample supply from February to April, the amount depending largely upon the temperature of the season and the rate at which the snow melts, whether gradually, giving a continuous flow, or rapidly, resulting in short, early floods, followed by droughts, as was the case in 1889. In this region stock raising is the principal industry, the tilling of the soil being of secondary importance. The settlers have taken up the land near each spring and along every stream, and have used the water according to the best of their ability. Both hot and cold springs are to be found along the foothills and near the Snake river, and most of these are now used for agriculture. In some instances the owners of these springs have built small reservoirs to hold the surplus waters, and they can thus irrigate comparatively large areas of ground. Other works of this kind are projected or are being executed as fast as the means of the settlers will allow.

One of the largest storage enterprises in the state is that of the Elmore County Irrigation Company, whose main reservoir is about 2.5 miles northeast of Mountain Home, a town on the Oregon Short Line. This reservoir has a surface area of nearly 560 acres. It is formed by an earth dam thrown across a narrow place on Rattlesnake creek. An additional supply will probably be obtained from Canyon creek by a feeding canal 30 feet wide on bottom, and other storage reservoirs may be built to increase the amount available. From the main reservoir the waters flow down the natural creek bed for a distance of 1.5 miles and are there diverted by canals, one toward the west to supply Mountain Home, the second toward the south, covering with its branches lands along both sides of the railroad. The lands under these canals are reported to be very fertile and adapted for the cultivation of fruit.

The Orchard Irrigation Company has a storage reservoir in this county, built for the purpose of reclaiming lands in the southern part of Ada and Elmore counties. Water is to be obtained from Indian creek, which heads on the south slope of the ridge separating the south fork of Boise river from the catchment area of small creeks emptying into Snake river. This stream is intermittent, being fed mainly by melting snow and rain waters. The reservoir has been formed by placing an earth dam across a canyon 100 feet in width. The greatest height of the dam is 65 feet, the bottom width 225 feet, and the top width 14 feet. The capacity of the reservoir is estimated to be, when filled to the bottom of the waste weir, 645,000,000 cubic feet. Water is drawn from the reservoir by means of a tunnel driven through the solid ground. About 2.5 miles below the dam the water is diverted from the natural channel into two canals, one running to the east and south and the other to the west, covering the town site of Bisuka. The total cost of the dam and tunnel is stated to have been $65,000. The lands to be irrigated will be set out mainly with prune and other fruit trees. An additional supply will probably be obtained from a second reservoir built on Blacks creek, north of Indian creek. Perpetual water rights have been sold at from $15 to $20 per acre.

IDAHO COUNTY is north of the center of the state, and extends from the Bitterroot mountains on the east to the Snake river on the west, thus reaching across the state. The greater part of the county is composed of mountain ranges, which have been but partially explored even for their mineral wealth. The agricultural land lies in the northwestern part of the county on the almost level divide known as Camas prairie, between Clearwater and Salmon rivers. The northern part of this prairie is in the Nez Perces Indian reservation, but the greater portion of this high, slightly rolling country is utilized for grazing, and to a small extent for agriculture. The Clearwater and Salmon rivers flow through deep canyons or narrow valleys 1,000 feet or more below the general level of the prairie, and their waters can not be diverted upon this large body of fertile land. There is usually sufficient rainfall to mature the crops, and farming operations have been successful except during the droughts of the past few years. On the low lands in the deep valleys along the Salmon river small gardens, orchards, and vineyards are irrigated mainly by the use of ditches built for placer mining, some of which have been abandoned by their former owners. On Camas prairie wheat, oats, barley, rye, flax, and timothy, and occasionally some vegetables, are raised without irrigation, and upon the whole dry farming is successful. It does not seem probable at the present time that any of this high land will be brought under irrigation, except perhaps close to the mountains at a few points where streams issue. This county may be said to be on the dividing line between the counties to the south, in which irrigation is the rule, and those to the north, in which it is the exception.

KOOTENAI COUNTY is at the northern end of Idaho, adjoining British Columbia, and comprising the comparatively narrow strip between the states of Montana and Washington. For the greater part it consists of mountains, generally well timbered, between which are many lakes, some of them of notable size. The agricultural land of the county lies principally on the Spokane prairie, a high, rolling tract along the Spokane river, extending in a belt 30 miles long and about 5 miles in width from Lake Cœur d'Alène to the city of Spokane, in Washington. The rainfall is usually sufficient to mature the crops, although severe droughts have been reported and the climate is favorable for the growth of all of the small grains and hardier vegetables. It is reported that corn does not mature, but is raised for fodder. Great difficulty is experienced on the Spokane plains in obtaining water for stock and domestic purposes, it being necessary in many instances to haul it for distances of from 2 to 5 miles. A number of wells have been sunk to a depth of from 80 to 320 feet, and from these water is obtained by pumping. No flowing wells have been found. On the eastern side of Pend d'Oreille and Cœur d'Alène lakes are low lands which are cultivated or upon which hay is cut, but in that locality there is no necessity for irrigation. In fact the settlers are more anxious to get rid of the excess of water than to obtain an additional supply. In springtime when the snow melts in the mountains the floods entering these lakes escape slowly through the narrow outlets below the lakes, and thus the water level is raised 15 or 20 feet or more, flooding the lower lands around the borders. The two instances where irrigation is practiced in this county are cases in which, owing to the exceptionally favorable location of the land, water can be brought to orchards and gardens.

LATAH COUNTY is south of Kootenai county, north of the Snake river, and lies principally on the head waters of the Palouse river and of tributaries of the Clearwater. The country is in the main a high, rolling prairie, into which the rivers have cut deep canyons. The rainfall is ample for raising crops and no irrigation is practiced, beyond, perhaps, the watering of a few gardens or fruit trees, which can hardly be called systematic irrigation. Wheat, oats, barley, flax, rye, and the hardier vegetables, as well as many kinds of fruits, thrive well and bountiful crops are produced on the rich, deep soil of the high, rolling lands. Although there have been several dry years the drought does not appear to have been so severe as to lead to serious losses or to suggest the necessity for irrigation.

LEMHI COUNTY lies along the Bitterroot mountains on the eastern side of the state. The Lemhi river flows in a general northwesterly course, mainly through an open valley, along the base of the mountains to its junction with the Salmon river, at which point Salmon city is located. Mining and stock raising are the principal industries, but irrigation is making gradual progress, water being taken mainly from the small streams which flow into Lemhi river from each side. Lemhi river is bounded by bench lands, portions of which are locally known as "bar lands". The soil on these "bar lands" is often better than that in the bottoms, but water from the main stream can not be taken out upon these areas, lying 100 feet or more above the stream, except by the construction of expensive canals. The smaller tributaries, however, having a rapid fall, can be readily diverted, and have been diverted in some instances. These smaller streams in many cases become nearly or quite dry in summer, and therefore are not as valuable for irrigation as the main stream would be. In the lower part of the valley near Salmon city questions concerning the rights of prior appropriators have given rise to lawsuits, which have somewhat retarded developments.

On the north fork of the Salmon in the northern end of the county are a few ranches in the narrow valley along the stream. Here the water supply is abundant for the small amount of agricultural land, the minimum discharge being estimated to be 60 second-feet. In the southern or southeastern part of the county also a few ranches have been established on the head waters of Birch creek and Medicine Lodge creek, both of which flow toward the Snake River plains, supplying water for agricultural lands in Bingham and Alturas counties.

LOGAN COUNTY is in southern Idaho, north of the Snake river, being the southern portion of the area formerly included in Alturas county. It extends from the foothills of the Wood River mountains on the north to the lava fields bordering the Snake, and contains in the northwestern corner the beautiful Camas prairie, one of many of that name, as well as a number of fertile valleys along the Wood river and its tributaries. The tilled lands of the county are near the foothills on the northern edge of the county, or along the valleys of the Big and Little Wood rivers and their tributaries. There are also small areas under cultivation down on the low lands within the canyon walls of the Snake. These lands are irrigated mainly from springs which issue from the precipitous sides of the gorge, some of them falling from a height of 150 feet or more. Here, also, along the river are many placer mines, and the water from the springs is employed for mining as well as for irrigation.

The Big Camas prairie is a broad, fertile tract lying in a general east and west direction, its length being about 50 miles and its width 6 to 8 miles. Malade river, or Camas creek, flows easterly through the center of the prairie, receiving on its way a number of small streams that come from the mountains to the north. These streams discharge considerable water at the time of melting snow, but in the latter part of June they diminish rapidly in volume, and in July and August little, if any, water reaches the Malade, although there may be a constant flow in the streams near the mountains. On June 28, 1889, Camas creek was measured above the backwater from the Wood river, and it was found to be discharging only 2 second-feet. The fall of the river is very slight, and water from the Wood river backs up for a distance of 6 miles.

Agricultural operations are almost entirely confined to the northern side of the prairie, at which point all of the water to be obtained in summer is utilized. In wet years crops can sometimes be raised successfully upon the prairie without irrigation, but in times of drought, as in 1889, even the small, comparatively well watered areas near the mountains suffer. Rye is often cultivated without the artificial application of water, and after alfalfa has once been started one crop a year can be obtained from the dry ground.

Along the Wood river, in the vicinity of Bellevue and Broadford, are many ranches, taking the full supply of that stream, except for a few weeks when the rivers are in flood. On the Little Wood river and its principal tributary, Silver creek, there are comparatively large areas of irrigated land. From these streams a great number of small ditches have been laid out, and there is no doubt among the farmers that the available water supply could be greatly increased if in place of these little ditches one or two well made canals could be constructed. In their lower courses the rivers flow over pervious beds, and thus lose a great part, if not all, of their water, and if canals with well puddled sides and bottoms could be constructed to cut off the meanders of the stream and carry the water with moderate velocity to the places where it is needed, a far larger acreage could be cultivated. One or two reservoirs are being constructed above narrow places along the rivers, and hopes are entertained of greatly increasing the crop area by this means. There was great loss of crops in 1889, not only on account of drought, but also through the ravages of grasshoppers. The damage done by these pests would have been greatly lessened if there had been ample water to irrigate the fields and prevent the development of the young insects.

Owing to the peculiar character of the soil, what is known as subirrigation is largely practiced, that is, the water is turned out of the laterals upon the fields. After saturating the surface it soon reaches an impervious layer, upon which it spreads laterally, wetting the ground at a distance beneath the surface. Enormous quantities of water are used in this way, and a good deal of it is wasted. Smaller ditches, dug nearer together over the field, would irrigate a larger area with less water.

A few measurements of river discharge have been made in this county by the United States Geological Survey, but no continuous records have been kept. The Wood river, as described in the statement concerning Alturas county, was measured near Hailey. On June 20, 1889, the river at that point was discharging at the rate of 300 second-feet, while 50 miles or more below, at the junction of Big and Little Wood rivers, its bed was almost dry. At the same time the Little Wood river at a point about 30 miles above the junction was discharging 30 second-feet, and its principal tributary, Silver creek, 170 second-feet, or in all 200 second-feet for the Little Wood. This added to the 300 second-feet in the Big Wood river at Hailey would make 500 second-feet, which, aside from the discharge from other sources, should theoretically be found at the junction, since a very small amount was being appropriated for irrigation. It thus appears that at least 500 second-feet was lost in the passage through the lava beds.

DISCHARGE OF WOOD RIVER AT HAILEY, IDAHO.

(Drainage area, 906 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
July	238	119	163	10,024	0.21	0.18
August	126	113	123	7,564	0.16	0.13
September	126	113	123	7,318	0.16	0.13
October	153	126	138	8,487	0.18	0.15
November	153	126	145	8,627	0.18	0.16
December	153	126	138	8,487	0.18	0.15

Nez Perces county is in the northwestern part of Idaho, opposite the southeastern corner of the state of Washington, and includes the country from the Snake river eastward along a portion of Clearwater river. The Lapwai, or Nez Perces, Indian reservation has until recently covered the greater part of the county back from the Snake river, and settlement has been retarded pending the opening of at least a portion of this reservation. The greater part of the county consists of high, rolling prairies, or table-lands, through which the streams flow in great ravines or canyons at a depth of from 200 to 500 feet or more below the general level. The altitude of these uplands is from 2,000 to 3,000 feet, and usually there is sufficient rainfall to produce fair crops of wheat, oats, rye, barley, corn, as well as potatoes and other vegetables. The soil is very fertile, and in years of abundant rainfall the crops are exceptionally large. Often, however, as in 1889 and 1890, the rainfall is deficient in quantity, and the crops, if not a total loss, are so scanty as hardly to repay the value of the seed and the labor of planting.

Water can not readily be taken to these plateaus on account of the depth to which the streams have eroded their channels. It is possible, however, that careful surveys may discover localities to which the streams can be conducted by long canal lines. The water supply from the Clearwater and its principal tributaries is excellent, but the smaller streams of the plateaus are very uncertain in their discharge. If found necessary as a protection against droughts, reservoirs can be built on the head waters of some of these small streams, especially in the vicinity of Craig mountains. In one case at least a small lake has already been utilized. As irrigation is not always essential on these high lands, it is doubtful whether many attempts will be made at present. On the low lands in the narrow valleys it is necessary to irrigate the gardens, orchards, and vineyards, as well as many of the field crops. The Lewiston Mining, Milling and Irrigating ditch from Clearwater river, 5 miles long and 4 feet wide on bottom, supplies water to a number of gardens and orchards at Lewiston, and there is also an irrigation ditch in the valley of the Sweetwater. Most of the irrigation in the county, however, is from small springs or by water raised by steam pumps, pulsometers, pumps driven by water wheels or by norias.

ONEIDA COUNTY is in southeastern Idaho, west of Bingham and Bear Lake counties and south of the Snake river. It is irregular in shape, a narrow projection from the southeastern corner extending along the Utah line across the northern end of the Cache valley to the summits of the Bear river range. It thus includes several distinct drainage districts, those of the streams flowing into the Bear river on the north, that of the Malade and its tributaries on the south, and the Cache valley streams on the southeast. The greater part of the county is mountainous, although the peaks, as a rule, do not rise to great heights. As a consequence of the general low altitude the water supply is comparatively small even for the narrow valleys, and is not sufficient to irrigate all the cultivated land, although this forms but a small proportion of the total amount arable. In the northern part of the county the valley along Bannock creek and the Portneuf river has been a part of the Fort Hall Indian reservation, and accordingly agriculture has not been developed along these streams. To the west of these, however, are a number of creeks flowing northward from the short mountain ranges, and each of them is used to its full extent in summer. The largest of these is Rock creek, along which in the vicinity of Rockland are irrigated areas of considerable extent.

In the southwestern part of the county are many valleys, some of them broad and containing thousands of acres of fertile land. The water supply from the hills is, however, very small, and cultivation is possible only in favored spots close to ravines from which small streams flow. At these points some forage is raised for the cattle which roam over the higher lands, where, as a rule, they find an excellent range. The Malade river receives the greater part of its water from the Bannock and Malade ranges to the east. Each of the tributary streams from these mountains is utilized at the point where it issues from its canyon, and a large portion of the northern and eastern edge of the Malade valley is thus irrigated. The farmers have found it impossible to water the whole of their land by the unregulated flow of the streams, and have attempted to construct storage reservoirs, but on account of lack of engineering skill and of capital not all of these have been successful. The Malade range, which separates this valley from Cache valley, is too low and too small in area to give rise to any very large streams, and as a consequence the greatest economy must be used in employing the waters upon the rich lands lying on either side.

In Cache valley is probably the largest body of level land in the county. The Bear river, coming from Gentile valley on the north, flows in a southwesterly course through narrow canyons, descending by rapids or small falls, and enters Cache valley through a deep gorge which it has cut in the ancient lacustrine sediments. The lands in the upper end of the Cache valley are 100 feet or more above the river, but the plain descends rapidly toward the south, so that in Cache county, Utah, the river is only a few feet below the general level. The part of the valley which is in Oneida county is so high above the river that up to the present time none of the water from Bear river has been used, except in the case of small ranches on the bottom land fringing the stream.

On the east side of Cache valley flowing into the Bear river are several large streams, each of which is diverted upon the lands extending out from the foothills toward the center of the valley. Several towns of importance have sprung up near the canyons of these streams, each depending upon the waters coming from the mountains. On the west side of Cache valley are enormous tracts of fertile land, extending from Deep creek to Western creek, for which no water is at present available. As previously stated, the Malade range, bounding the valley on the west, does not furnish sufficient water for the needs of the small agricultural towns, and water storage has already been found necessary, at least four reservoirs being under construction.

Surveys have been made to demonstrate the possibility of taking water from the Bear river at some point in the canyons below Gentile valley, and it has been found that there is sufficient fall to the river to allow of a canal being taken out to cover this west side land, but the difficulty of constructing and maintaining a canal in the sides of the steep bluffs of unconsolidated materials is so great that it is questionable whether such a canal would be profitable. By utilizing the storage facilities of Bear lake, mentioned in the description of Bear Lake county, it is probable that sufficient water can be secured for such an enterprise even after the lower canals have been supplied.

The measurements of water flowing in the Bear river made by the United States Geological Survey have been at two points, the first at Battle creek, at the head of Cache valley, in Oneida county, and the second near Collinston, in Boxelder county, Utah, below Cache valley. The discharge at Battle creek varied from 270 to 5,980 second-feet in 1890. (*a*)

---

[a] The average for two years was 1,423 second-feet. This amount of water flowing throughout the year is equivalent to 1,030,252 acre-feet. The drainage area is

On some of the fertile lands to which water can not be brought, dry farming, that is, farming without irrigation, has been attempted, often with successful results. In fact, many of the farmers state that although the yield per acre is smaller, the returns as a whole are greater than on irrigated land, from the fact that larger acreages are tilled with less labor and expense, and thus the cost per bushel of product to the farmer is less. Rye, wheat, and corn are reported to be the principal crops thus raised, the greatest acreage being that in rye. As a general rule, however, it may be said that irrigation is necessary in this county, and it is only when water can not be had that more precarious methods of agriculture are attempted.

Irrigation is carried on by means of small ditches built by the farmers individually or in partnership, or occasionally by corporations whose members are the irrigators using the water. Most of the agricultural towns are incorporated, and the management of the water is assumed by the town officers. In this case, however, since all of the voters are farmers, the control is practically in the hands of irrigators. Many of the ditches have been built for so many years, and have been so often enlarged that it is impossible to ascertain either their cost or dimensions. Irrigation is usually begun about May 1, water being used upon the lucern, or alfalfa, and one good irrigation insuring a crop. By the time these fields are irrigated the small grains need water, and the alfalfa receives no more until these are harvested. The grains usually require three waterings at intervals of about 18 days, the practice varying, however, with different individuals. If there is plenty of snow in January and the wind blows it into drifts the farmers can expect a good supply of water in June and plant a full acreage. They are accustomed to regulate to some extent the area of ground cultivated by the appearance of snow in the mountains and the probable amount of water to be received. If there is an excess of water in the fall, it is frequently turned upon the ground in the hope of securing a saturation sufficient to be of benefit the next spring.

OWYHEE COUNTY is in the southwestern corner of Idaho, adjoining Oregon and Nevada. The Snake river forms the northern boundary, and receives the drainage of the county by a number of streams, most of which are short and carry a small volume of water. The Owyhee river, rising in the mountains of northeastern Nevada, flows across the southwestern corner of the county into Oregon and finally enters Snake river a short distance north of the county line. This river receives most of the streams that rise in the western side of the county.

The great lava sheet of southern Idaho extends from the east, halfway across this county, forming a great plateau with a rough, barren surface. The Snake river has cut across this plateau, forming a deep, narrow gorge, which widens in places, and is occasionally fringed with bottom lands. The larger tributaries also have cut deep ravines or gorges in the lava, making long, narrow valleys, while the smaller creeks issuing from the mountains

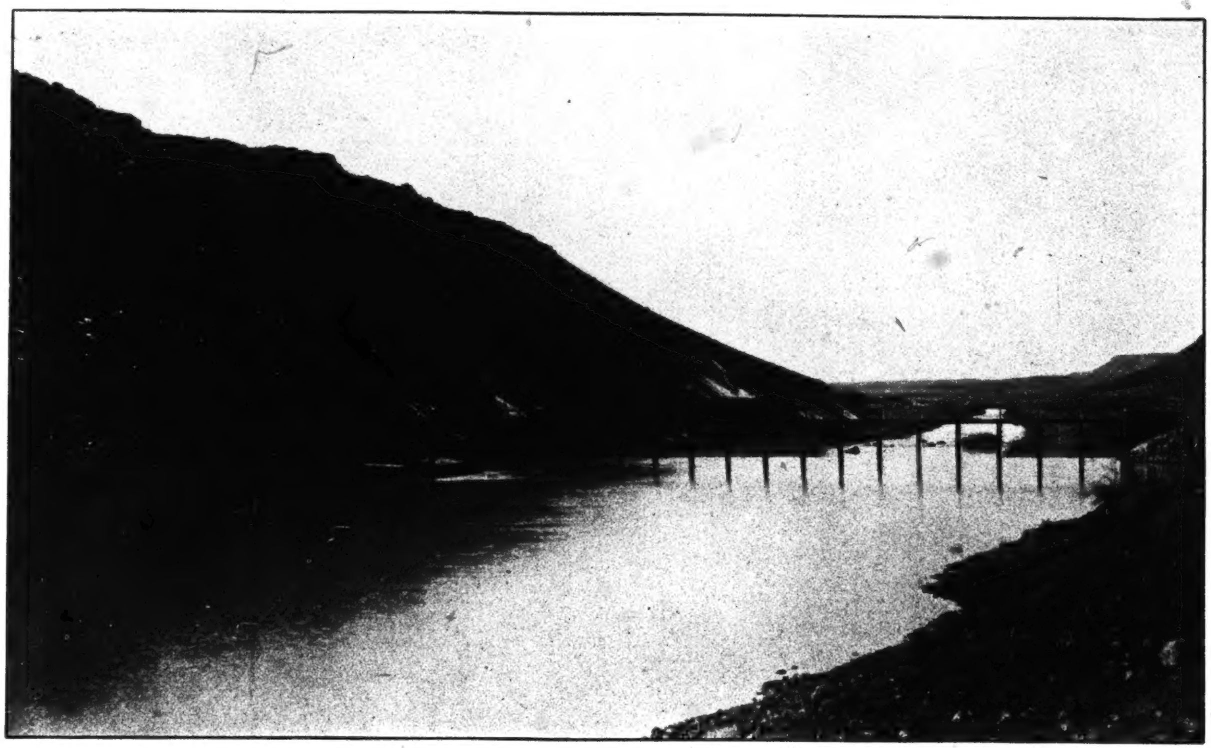
---

about 4,500 square miles, and this water if placed upon a plain of the same size would cover it to the depth of 4.3 inches. The following are the gaugings for a series of years:

DISCHARGE OF BEAR RIVER AT BATTLE CREEK, IDAHO.

(Drainage area, 4,500 square miles.)

Months.	Discharge in second-feet.			Total for month in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
October 11 to 31	420	300	355	21,832	0.09	0.07
November	830	430	487	28,976	0.12	0.11
December	735	350	565	34,747	0.14	0.13
1890.						
January	1,255	270	875	53,812	0.22	0.19
February	2,040	600	809	44,900	0.18	0.18
March	2,040	780	1,271	78,166	0.32	0.28
April	3,960	2,170	2,978	177,191	0.74	0.66
May	5,980	3,960	5,199	319,738	1.33	1.60
June	5,980	2,300	4,074	242,403	1.01	0.91
July	2,170	1,200	1,582	97,293	0.40	0.35
August	1,200	880	1,000	61,500	0.26	0.22
September	880	780	843	50,158	0.21	0.19
October	880	780	854	52,521	0.22	0.19
November	880	780	783	46,588	0.19	0.17
December	780	690	748	46,002	0.19	0.17
Per annum	5,980	270	1,751	1,270,272	5.27	0.42
1891.						
January	690	690	690	42,435	0.18	0.15
February	....	....	780	43,290	0.18	0.17
March	880	780	790	48,585	0.20	0.17
April	2,950	780	1,623	96,500	0.40	0.36
May	3,030	2,440	2,652	163,098	0.68	0.59
June	2,870	1,680	2,245	133,578	0.56	0.50
July	1,660	980	1,288	79,213	0.33	0.29
August	980	780	835	51,352	0.21	0.19
September	980	690	798	47,481	0.20	0.18
October	980	980	980	60,270	0.25	0.22
November	980	880	957	56,941	0.24	0.21
December	1,910	880	1,053	64,759	0.27	0.23
Per annum	3,030	690	1,224	887,511	3.70	0.27
1892.						
January	800	800	800	49,200	0.21	0.18
February	880	780	855	49,162	0.20	0.19
March	1,540	880	1,304	80,196	0.33	0.29
April	2,040	1,540	1,824	108,528	0.45	0.41
May	4,370	2,040	2,710	166,665	0.69	0.60
June	5,260	3,200	4,446	264,537	1.10	0.99
July	3,200	1,540	2,345	144,217	0.60	0.52
August	1,420	880	1,025	63,037	0.26	0.23
September	880	780	793	47,183	0.20	0.18
October	780	780	780	47,970	0.20	0.17
November	780	600	687	40,876	0.17	0.15
December	880	880	880	54,120	0.23	0.20
Per annum	5,260	600	1,537	1,115,619	4.64	0.34



VIEW OF BRUNEAU DAM AND CANAL, OWYHEE COUNTY, IDAHO.

are often lost in the porous mass, to reappear probably as springs in the deeper valleys. The Bruneau is the principal river in the eastern end of the county. It rises in the mountains of Nevada north of the sources of the Humboldt river. This stream flows northward through deep canyons and furnishes a perennial supply, which can be used in irrigating the lower valleys. About 12 miles from the mouth of the river the canyon walls open, forming the Bruneau valley, which extends for about 8 miles, averaging 1 mile in width. The valley lands are very fertile, but are only irrigated to a small extent by a few farmers' ditches. The surrounding country is used as a winter range for sheep, herds aggregating thousands of sheep being kept there during the winter months. At the lower end of Bruneau valley the river enters a rocky canyon, through which it has an average fall of about 10 feet per mile.

The principal irrigation project is that of the Owyhee Land and Irrigation Company, organized for the purpose of bringing under irrigation a tract of about 60,000 acres lying on both sides of the Snake river, it being proposed to cross the river by means of a flume. This company has constructed a dam across Bruneau river about 1.5 miles above its mouth. (*a*) The dam, shown in the accompanying illustrations, consists of a rock filled foundation 25 feet high, 190 feet wide on bottom, and 180 feet from side to side of the canyon. Upon this foundation is a timber crib dam 176 feet long on the crest, terminating at each end in vertical masonry abutments. At the south side are the head gates of the canal, having an opening of 40 feet in width. From this point the canal follows the contours in a general westerly and northwesterly direction at a distance of from 1 to 2 miles south of the Snake river.

In the northwestern corner of the county are small mountain ranges, from which streams flow in all directions, those toward the north and east directly into the Snake, and those to the south and west into the Owyhee. The snow on these mountains melts early in the spring, and as a consequence the floods occur in April or May, some weeks earlier than in the high mountains farther to the east around the head waters of the Snake. The water begins to diminish early in the summer, and many of the streams are dry by the latter part of June or in July, so that occasionally when the grain is well headed out it is impossible to secure sufficient water to completely mature it. These mountains are among the largest gold and silver producing areas in the state, and as a consequence there is a good local market for agricultural produce. There are several small valleys among the mountains, the agricultural land being at an elevation of less than 5,000 feet. Among them may be mentioned Pleasant valley, on the head waters of Jordan creek, and opening toward the west into Oregon, the portion in that latter state being known as Jordan valley.

SHOSHONE COUNTY includes the high mountain region west of the Bitterroot mountains and east of Nez Perces, Latah, and Kootenai counties. It contains the head waters of the Clearwater and Cœur d'Alène rivers. It is a mining region, and also contains excellent grazing areas. For the most part it is heavily timbered, and what little farm produce is raised is successful without irrigation. At the altitude of the cultivated lands of the valleys there is sufficient rainfall to produce wheat, oats, timothy, and the ordinary vegetables. Summer frosts are apt to occur, and are of more injury than a scarcity of water.

WASHINGTON COUNTY is on the western side of Idaho, lying along the Snake river. It includes the drainage basin of the Weiser river and a very small part of the head waters of Little Salmon river, and also on the west the narrow strip of country draining into Snake river. Along the Weiser is a succession of valleys, in each of which agriculture has been gradually developed, mainly as an adjunct to stock raising. In the highest of these valleys fair crops are sometimes obtained without irrigation, but success is not always certain, and the yield is less than that on well irrigated land. Small ditches have been built by the farmers to bring the water of the tributaries of the Weiser, and in some cases that of the river itself, upon the lands adjacent to the stream, but most of these ditches are very small and poorly constructed, from the fact that the farmers are poor and have had little experience in handling water to the best advantage. In the lower part of the county near the Snake river are larger ditches built by associations, and there is also a canal from the Payette river, as mentioned in the description of Ada county, extending northerly into this county.

Many of the streams, especially those coming from the west into the Weiser, are dry in summer, and as a general thing the water supply throughout the county becomes scanty after the first of July. This was especially the case in the great drought of 1889. Along the bottom lands good crops are occasionally secured by means of the moisture which saturates the ground when the streams are high, but even on these lands during the recent droughts very little was raised. Water storage is believed to be a necessity, and the irrigators have discussed the matter and designated various places which might be used. One or two individuals have built small storage works, but the greater number of the irrigators have about exhausted their means in digging the small ditches. In this county large tracts have been taken up by men too poor to improve more than a small fraction of the land, but who are struggling along in the hope that either the government or some great corporation will construct irrigation works that will be of benefit to them.

As an example of the ditches, may be mentioned the Farmers ditch, in Council valley, taking water from the Weiser river, about 6 miles from Council valley post office, and bringing it out upon the east side. The length of

---

[a] The discharge of the river at this point on June 1, 1892, was estimated from float gaugings to be 3,500 second-feet, this probably being the maximum for the year. It was also estimated from flood marks that the greatest known flood discharged at the rate of 7,000 second-feet.

this ditch is 6 miles, and its bottom width 4 feet. It is owned and is being completed by private parties, each share entitling the owner to 50 miner's inches. Farther down, in Indian valley, is the Indian Valley and Gray Creek ditch, taking water from the Little Weiser river and carrying it in a northwesterly direction. It is 7 miles long, 5 feet wide, cost $1,350, and is owned by a corporation, each share entitling the owner to 100 miner's inches of water. The annual assessment per share for cleaning and repairing the ditch is $8, and if the duty of water is 1 inch to the acre, the annual cost will thus be only 8 cents per acre. The stream occasionally dwindles in summer to a quantity so small that the shareholders can not always obtain as much as they wish. In fact, the farmers on all the smaller streams in this vicinity suffer more or less for want of water at critical times.

The Middle Valley Irrigation ditch takes water from the east side of the Weiser river, carrying it southward about 4 miles. Its average width is 8 feet, its capacity, approximately, 20 second-feet, and its cost, $6,000. There is plenty of water in the river at this point, and no complaint of loss of crops. On Mann creek, in the southern end of the county, is a ditch taking water from the east side and carrying it a distance of 8 miles. The average width is 3 feet, and the cost about $2,000. As an example of prior rights may be cited the case on this creek, different in no way from the conditions obtaining in other parts of the country. Here 8 ranches have prior rights, while other ranches, to the number of nearly 30, have secondary claims to the water. In time of drought these 8 ranches have the entire stream, while the others, equally good in every respect, must suffer. Measurements of the discharge of the Weiser river have been made by the United States Geological Survey at the mouth of the canyon, 9 miles above Weiser, and computations of daily discharge have been made. (*a*)

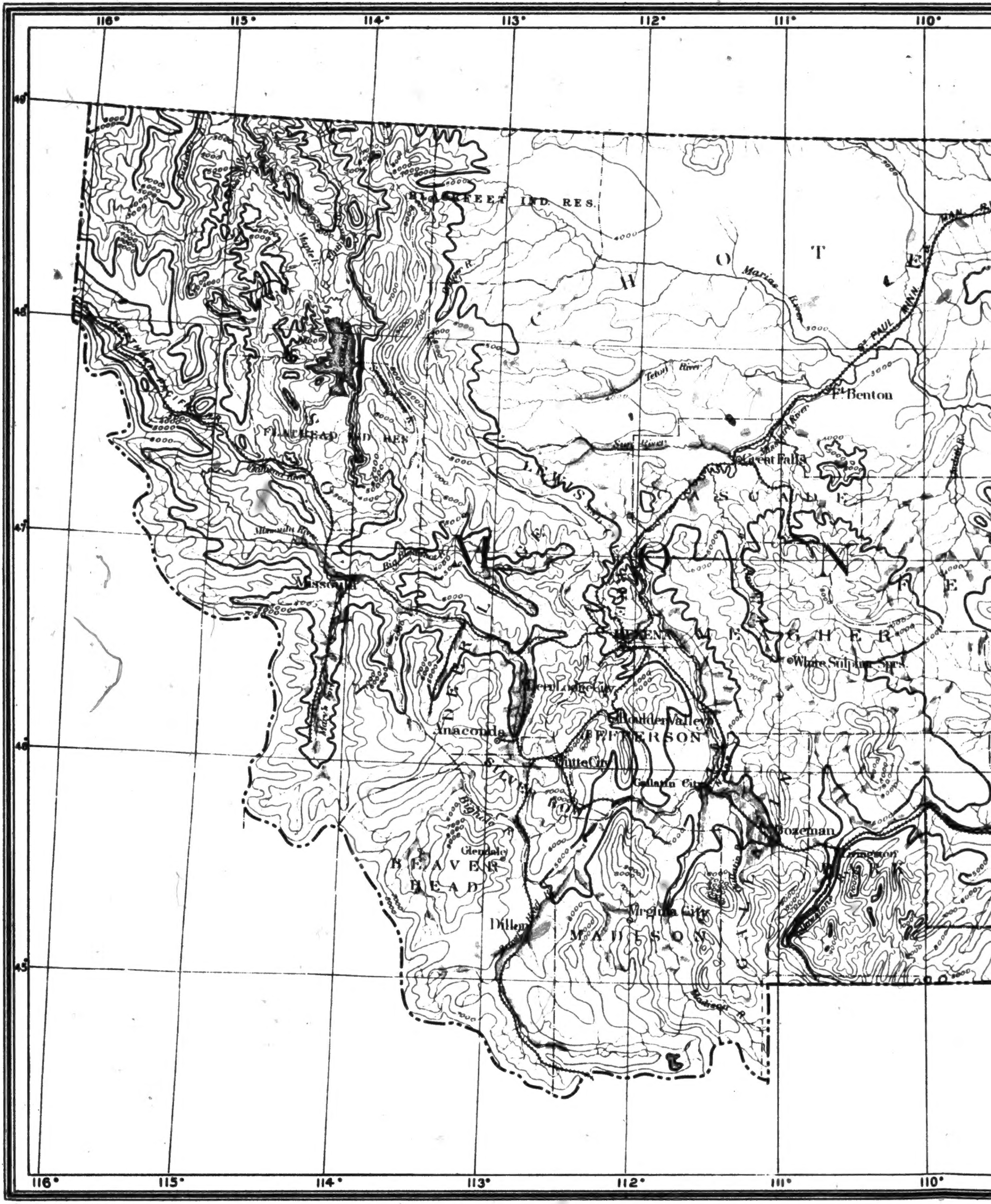
---

a As continued since 1890 the measurements cover a period of nearly two years:

DISCHARGE OF WEISER RIVER IN CANYON, IDAHO.

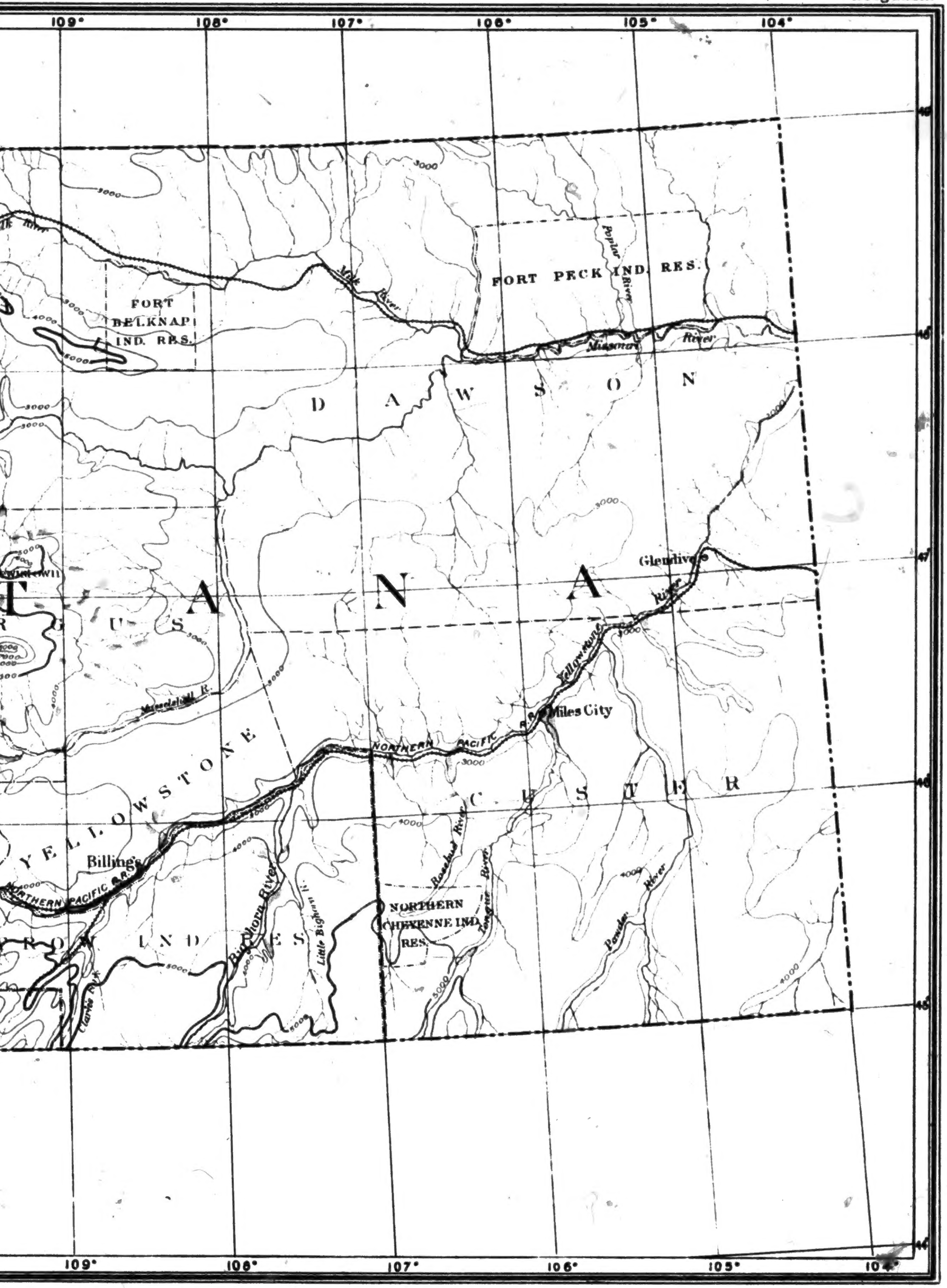
(Drainage area, 1,670 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.		MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.		Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1890.							1891.						
March 13 to 31	11,220	1,550	5,773	355,039	3.99	3.45	January	320	190	292	17,958	0.20	0.17
April	7,060	2,470	4,792	285,124	3.20	2.87	February	1,860	320	678	37,620	0.42	0.41
May	7,060	2,610	4,882	300,243	3.37	2.92	March	9,300	1,010	2,855	175,582	1.97	1.71
June	2,470	1,280	1,792	106,624	1.20	1.07	April	2,220	1,260	1,777	105,731	1.26	1.06
July	1,130	220	590	36,285	0.41	0.35	May	1,640	1,010	1,331	81,856	0.93	0.80
August	190	100	138	8,487	0.09	0.08	June	1,010	500	703	41,828	0.47	0.42
September	140	80	103	6,128	0.07	0.06							
October	190	140	166	10,209	0.11	0.10							
November	400	160	222	13,209	0.15	0.13							
December	480	280	396	24,354	0.28	0.24							


116°
115°
114°
113°
112°
111°
110°
49°
48°
47°
46°
45°
BLACKFEET IND. RES.
CHOTEAU
Marias River
Teton River
ST. PAUL MINN. & MAN. R.R.
Ft. Benton
Sun River
Great Falls
FLATHEAD IND. RES.
Flathead
MISSOULA
Missoula
Missoula River
Big Blackfoot R.
LEWIS
CASCADE
MEAGHER
FERGUS
Helena
White Sulphur Sprs.
Deer Lodge City
Anaconda
DEER LODGE
Boulder Valley
JEFFERSON
Butte City
SILVER BOW
Gallatin City
Bozeman
Livingston
PARK
Yellowstone R.
Glendale
BEAVER HEAD
Big Hole R.
Dillon
Virginia City
MADISON
GALLATIN
Madison R.
Bitter Root R.
3000
4000
5000
6000
7000
8000

Sackett & Wilhelms Litho. Co. N.Y.

MAP OF MONTANA SHOWING AR


109°
108°
107°
106°
105°
104°
3000
FORT BELKNAP IND. RES.
FORT PECK IND. RES.
Poplar River
Milk River
Missouri River
D A W S O N
N A
Glendive
Yellowstone River
Miles City
Musselshell R.
Y E L L O W S T O N E
NORTHERN PACIFIC R.R.
Billings
C U S T E R
Rosebud River
Tongue River
Powder River
Bighorn River
Little Bighorn R.
Clarks Fork
NORTHERN CHEYENNE IND. RES.
R O W I N D R E S
4000
5000

AS IRRIGATED IN 1889.

IRRIGATED ▨

MONTANA.

Total population (average per square mile 0.91)		132,159
Number of owners of farms (4.24 per cent of population)		5,603
Number of irrigators (66.14 per cent of farm owners, 2.80 per cent of population)		3,706
Area of state, land surface (145,310 square miles)	acres..	92,998,400
Area irrigated in census year	do...	350,582
Area of all farms, 46.61 per cent improved	do...	1,964,197
Cereals raised in census year, including 13 acres in buckwheat and 14 acres in rye	do...	77,162
Barley, average production, 34.59 bushels per acre	do...	4,652
Corn, average production, 13.96 bushels per acre	do...	1,019
Oats, average production, 29.10 bushels per acre	do...	52,768
Wheat, average production, 24.48 bushels per acre	do...	18,696
Alfalfa	do...	2,522
Total value of all farms, including land, fences, and buildings		$25,512,340
Estimated total value of the farms irrigated in whole or in part		$17,354,000
Estimated value of all farm productions (sold, consumed, or on hand) for 1889		$6,273,415
Estimated value of productions, as above, from farms irrigated in whole or in part		$4,544,000
Average size of irrigated farms	acres..	95
Average size of irrigated farms of 160 acres and upward	do...	307
Per cent of acreage of irrigated farms of 160 acres and upward to total acreage irrigated		50.37
Average size of irrigated farms under 160 acres	acres..	56
Average first cost of water right per acre		$4.63
Average annual cost of water per acre		$0.95
Average first cost per acre of preparation for cultivation		$8.29
Average value of irrigated land, including buildings, etc., in June, 1890, per acre		$49.50
Average annual value of products per acre in 1889		$12.96

GENERAL DESCRIPTION.

In area of land irrigated in 1889, Montana was third, coming after California and Colorado. This was due primarily to the large average size of irrigated farms, 95 acres, for as regards number of irrigators the state is fifth, Utah and Idaho, as well as the states named, having a greater number. As a result of the large average size the value of lands and of products was considerably below the average for the whole western United States, by far the greater part of the crop raised consisting of forage plants. Over one-half of the area of the irrigated lands of the state was in individual holdings of 160 acres or over in size, while the remaining holdings, what may be known as small farms, averaged 56 acres each, in this respect standing next to Nevada, where the irrigated areas were largest. The first cost and value of water rights were relatively low, and also the average first cost of cultivation per acre.

The agricultural development of the state, owing to its arid climate, has been governed directly by the relative position and altitude of the mountain masses and the resulting water supply. By the position of the main ranges, trending in a general northerly and southerly direction, long valleys have been formed following the same general course, as, for example, those of the Missouri below the Three Forks and of Smith river on the east of the Belt range, while other ranges projecting out toward the prairies partially encircle great basin like valleys. The altitude of the mountains determines to a large extent the water supply of the lands at their bases, the effect of altitude being modified, however, by the direction of the prevailing winds. Most of the tilled land, as well as the majority of the population and the bulk of various industries, is found among the mountains in the western half of the state. The broad valleys in which agriculture is practiced are in few cases less than 4,000 feet in altitude, the greater part of the land now under cultivation being at an elevation of from 4,000 to 5,000 feet.

Taking the area of the state as a whole, it has been ascertained that 49 per cent is under 5,000 feet above sea level, 21 per cent from 5,000 to 6,000 feet, 14 per cent from 6,000 to 7,000 feet, 9 per cent from 7,000 to 8,000 feet, and 7 per cent over 8,000. This distribution of altitude must be taken into consideration when discussing the agricultural possibilities of the state, for high mountain masses furnishing perennial streams are as important to future development as low lying valleys with a fertile soil and a genial climate. The great problems to be solved and the doubts as to agricultural possibilities relate mainly to the vast low lying areas not broken by lofty mountains.

Montana is the most northerly state wholly within the arid region, and thus probably, taking all things into consideration, the agricultural land requires as a whole less water than that of any other state, although it may actually receive as much or more. In fact, in the northwestern part of the state crops are often raised without irrigation, the rainfall in ordinary seasons being sufficient for all needs. This extreme corner may be said to lie in the subhumid region. Even here, however, there are years of drought, as 1889 and 1890, when crops were almost a complete failure, and the necessity of irrigation as a means of insurance against loss is apparent. Many of the bottom areas, and even of the benches, when not irrigated yield in favorable years from one-half ton to 1 ton of hay per acre, this quantity, however, being increased several fold where irrigation is practiced. Some of the stock raisers state that hay raised without the artificial application of water, though less in quantity, is much better in quality, as irrigation destroys certain of the valuable native grasses.

In many parts of the state the rainfall is usually sufficient to bring the crops almost to maturity, and often only one watering is required. The grain may be nearly ripe when the dry, hot winds sweep down upon it, parching the vegetation and the soil. If water is not then at hand in abundance all of the past labor will be a complete failure, but with the application of water at this critical period the grain will fill to an abundant harvest. This one watering then is as essential to the success of the crops as are the three or four waterings of the more arid sections, for without it the crops are ruined. Thus, the necessity of irrigation is as great as in states farther to the south, although the quantity of water and the time required in applying it may be less.

FLUCTUATIONS OF WATER SUPPLY.

The quantity of water flowing in some of the larger streams of the state has been measured and computations have been made of the daily fluctuations, the results being given in the descriptions of the counties where the gaugings were made. From these figures the average monthly fluctuations have been computed, showing the changes which take place from month to month. Without water storage or regulation of the annual discharge the value of the river is governed largely by the amount of water which flows during the latter part of the crop season, that is to say, the acreage is limited to a certain extent by the quantity of water available in July and August rather than by the average amount discharged. The percentage of flow for each month is therefore given in the table below in connection with the monthly distribution of rain. Comparison should be made with similar results obtained for rivers in Idaho.

Reducing this matter to the simplest statement, it is seen that in May and June 44.4 per cent of the water was discharged, or nearly one-half the total quantity for the whole year, while in July and August only 13 per cent and 7 per cent, respectively, flowed in the streams. Most of this flood water of May and June comes from melting snow, the spring rises being due rather to increase of temperature than to direct precipitation. The mean annual rainfall for the entire state is about 15 inches, varying greatly, however, with the altitude of the locality, the high summits probably receiving upward of 30 inches of water, mainly in the form of snow, while the lower plains may receive 10 inches a year or even less. This amount of rain, if it were precipitated mainly during the winter or distributed evenly throughout the year, would be of less value than at present for agricultural purposes, but fortunately the greater part falls during the crop season, as shown by the following table, made by the compilation of records from the stations of the signal service located in different parts of the state, most of these being, however, in the valleys. This table gives the average rainfall for all years and stations, the results being shown in inches and in percentages of the whole.

AVERAGE MONTHLY RAINFALL AND RIVER FLOW IN MONTANA.

MONTHS.	RAINFALL.		River flow. (Per cent.)
	Inches.	Per cent.	
The year	14.7	100	100.0
January	1.0	7	3.6
February	0.6	4	3.7
March	0.9	6	3.8
April	1.0	7	6.4
May	2.5	17	21.2
June	2.4	16	23.2
July	1.3	9	13.0
August	1.4	9	7.0
September	1.0	7	4.7
October	1.0	7	5.0
November	0.7	5	4.4
December	0.9	6	4.0

From the preceding table it is seen that the rainfall during May and June was on an average one-third that of the entire year, while that of July and August was a little over one-half that of the previous 2 months, but greater than during any other season of the year, the distribution of the rainfall by months being on the whole favorable for agriculture. The annual distribution of the rain is of more than usual interest in connection with the crops of the census year, for 1889 and 1890 were known as years of drought. Comparing the rainfall as measured for the last decade at several stations in Montana, it is found that for these localities the average is as follows: in 1880 the total depth of rain was 14.5 inches; in 1881, 13.8 inches; 1882, 12.6; 1883, 12.6; 1884, 17.2; 1885, 11.7; 1886, 12.1; 1887, 16.4; 1888, 13.5, and in 1889, 9.5 inches. The most prominent feature about this record is the great rainfall of 1884, a year when there was an unusual abundance of water throughout the west and the rivers were extraordinarily high. On the other hand, is to be seen the deficient rainfall of 1889, when the rivers shrank in many instances far below the level of previous years. These fluctuations in the amount of rainfall year by year are to be found not only in the arid region but throughout the world, but in dry countries they are more noticeable from the fact that all occupations and land values are intimately connected with the supply of water.

DEVELOPMENT OF IRRIGATION.

Montana includes on the east a portion of the Great Plains region and on the west a part of the continental divide, the state extending beyond the main range of the Rockies to the Bitterroot mountains, on the western border. There is thus a wide difference in topography from the serrated peaks and narrow valleys, watered by perennial streams, to the broad expanse of the prairie, whose soil and vegetation are dry and parched during a great part of the year. The progress of settlement has been governed by these topographic features. Following on the hunters and trappers who first explored these regions came the wandering stock men, who settled on the bottom lands in the valleys of the western part of the state. The slow natural transition from pastoral industries to the tilling of the soil was soon broken by discoveries of precious metals among the mountains, and in the rush to the mines agriculture and stock raising became of little relative importance. The necessity, however, of supplies for the mining camps soon encouraged the growth of agriculture and stimulated it to a development far in excess of that which would have taken place in the ordinarily slow growth of a farming community.

The ease with which water could be brought upon the land and the favorable location of mines, furnishing a market for the sale of produce, have caused western Montana, indirectly because of its mountains, to be the most thickly settled and well cultivated part of the state, while the eastern plain or prairie region, with its almost boundless extent of fertile soil and its great rivers, the Missouri and Yellowstone, is still thinly settled. The area irrigated by large canals is comparatively small, and by far the greater part of the irrigation of the state is done by means of small ditches taken from the rivers each to cover one or two ranches. Deducting the acreage covered by the few great canal systems of the state, it has been found that on an average there is an independent ditch for every 225 acres of crops. This figure gives some conception of the difficulties to be encountered in attempting any systematic division of the waters, for in cases of controversy the exact status of each of these little ditches must be ascertained in its relation to the whole water supply and to the claims of all other ditches taking water from the same source.

Throughout Montana, as a rule, the construction of the ditches and irrigating works has been of the most temporary character, although there are a few notable canals well planned and built at great expense. Most of the irrigated area, however, is covered by ditches dug by the farmers without preliminary survey. Many even have been merely plowed out, the water then washing its own channel. The streams are diverted into the head of the ditches usually by temporary obstructions of brush, logs, rocks, and earth, replaced after each freshet. In other cases the bed of the canal is made so low that the water will flow in without diverting dams. In some cases, where the fall of the ground is not sufficiently great to allow of bringing the water out of the river at all times, the so-called high water ditches have been built, receiving water only in times of flood, the bottom of the ditch being above the low water level of the river. In this way a large quantity of water is taken during the spring, and the ground is thoroughly saturated, so that one crop of forage is assured. This irrigation is of the most crude character, but the resources of the irrigators have not been such that they can improve upon it.

METHODS OF IRRIGATING.

The various forage crops are usually flooded; the small grains are irrigated by systems of little furrows, while corn, potatoes, and other vegetables are wet by allowing the water to flow between the hills or beds. In applying the water to the soil it is generally the custom to use a stream flowing at the rate of about 80 to 100 miner's inches, or approximately 2 second-feet. With a less quantity of water a greater time is required in watering the crop, and the stream travels so slowly from point to point that a large part is lost on the way. On the other hand, by attempting to use a much greater amount, the land is badly washed in places or an excess of water is applied. Hay and meadow lands are irrigated from early spring until late in the fall. Wheat, rye, and barley are generally irrigated but once during the season, unless it is unusually dry. Potatoes are irrigated once or twice, and other vegetables may be watered every 10 days or 2 weeks. Oats generally receive two irrigations.

The time required for the irrigation of a field varies with all these details, and perhaps in no one item does individual peculiarity stand out more prominently. One man turns out upon his ground as much water as he can procure and leaves it even for a day or more at a time, while another whose experience has perhaps been different, or whose soil requires special treatment, carefully conducts the water from point to point, and continually opens or closes his small earth dams.

The time of the year during which irrigation is practiced is also accountable for some diversity of method. In general the water is used from the time the rivers begin to rise to the freezing of the water in the fall. In time of flood, however, some of the irrigators turn all the water possible upon the higher lands in order to saturate them and produce an early crop of alfalfa. This is especially the case with those irrigators who have only the right to an excess of water, for it is essential to employ it at the time it is available, and they hope by the aid of fortunate rains to produce an early crop. Many of the older farmers who feel secure in their water rights do not employ irrigation until the appearance of the crop shows it to be absolutely necessary. Others use water throughout the year, flooding meadow lands, and employing it at various times on the different crops. Thus the number of waterings can not be reduced to any definite statement.

Owing to the scarcity of water it is customary in many localities to irrigate only a portion of a farm during any one year. For example, a farmer having 100 acres may use the water only on 50 acres and let the remainder lie fallow, and the next year use the water on the fallow land of the year before. A greater yield per acre is claimed as the result of this alternation. This method introduces some confusion in any statistical investigation, for, on the one hand, the farmer has 100 acres under irrigation, and yet, owing to the scarcity of water, he is not able to irrigate more than half of it in any one year, and perhaps in years of drought, as in 1889, can not produce a crop on more than one-third or one-fourth of the total.

WATER CONTROL.

Up to the present time the control of the water for the greater part of the irrigated area has been in the hands of the irrigators themselves. They have built and now own and manage the means of distributing the water, but there now remain few opportunities for the construction of small ditches. More difficult engineering feats must be attempted, requiring larger capital, and canals must be built by outside aid. The ditches built by corporations are as a rule more expensive than those dug by the farmers, since they usually cover areas more difficult of access. The first cost of water is thus greater, and the annual charge for bringing water to the land must necessarily be larger than that estimated as the present average cost. The charges of water companies range from $1 to $2.50 per year per acre, while the farmers estimate that on an average the annual cost to them is only 95 cents per acre. This charge of the water company is usually a burden to the irrigator, and he is inclined to look upon canal companies in general as extortioners and the rates asked as exorbitant, although as a matter of fact these may not yield a fair interest on the investment.

Some of the larger irrigation schemes have been of a decidedly speculative character, being stocked for a large sum with only a small amount actually paid in or expended on work. A claim is usually filed for all the water in the river, the amount being often in excess of the total discharge of the stream, the object apparently being to sell the franchises of the company at an early stage to other parties or to dispose of the stock. The present condition of irrigation development and of the control of the waters of the state is by no means satisfactory to the farmers, and most of them look forward to improvements in methods of irrigation and in legislation. As the matter now stands, the additional area annually brought under irrigation is rapidly increasing, in spite of the fact that along nearly all the smaller streams the present area under ditch is in excess of the amount that can be successfully watered in such years as 1889 and 1890. On the one hand the older settlers, those who legally should have prior right to the water to the extent of their original appropriation, complain that in spite of their legal rights the later comers are taking water at points farther up the stream, where it can be diverted more easily, and that by this rapid encroachment they themselves are being brought almost to the verge of famine. They can no longer obtain water in times of scarcity, and consequently their lands have little value, and for every new ranch higher up the stream one or more old ranches must suffer.

On the other hand, those who have come into the country at a later date and who have pushed farther up the rivers, who have made for themselves homes and have invested all their capital and labor in irrigating their lands, assert that the owners of prior rights have no consideration for others; that these old settlers will, if they can, take all the water in the stream regardless of others, and often use it carelessly or even waste it, while others are in want; or that during the drought of summer it is useless to let the water run in the bed of the stream beyond their own ditches, as before the slender stream can reach the heads of the ditches farther down the valley the entire amount either sinks or is evaporated, and therefore, since the owners of prior rights can not be benefited, those who can use the water should be allowed to do so.

These complaints form the two extremes, and between them are innumerable cases with every shade of right and wrong involved. The consequence is that during every period of drought there are conflicts arising over the proper distribution of the water. Resort to the ordinary courts of law often yields but little satisfaction, for the delays appear interminable, and even when a decision is reached, yet not being based upon actual and continuous measurements of the water available and on other engineering details, it is often of little practical value, from the fact than in many instances more water is awarded than actually exists, or new circumstances may have arisen entirely obviating the points passed upon. The great necessity is felt for immediate definite judgments based upon an accurate knowledge of the amount of water available and the demands upon it. Great interest is felt in the practical operations of the Wyoming laws in this matter.

ARTESIAN WELLS.

The principal group of flowing wells in the state are those in the vicinity of Miles city, Custer county. These are from 180 to 600 feet in depth, the largest amount of water being obtained, it is stated, about 170 feet below the surface. Several of the deep wells in this vicinity do not flow, but water is raised to the surface by means of windmills. Flowing wells are also found not far from Albright, 35 miles west of Miles city. The wells discharge from 5 to 200 gallons a minute of water suitable for household purposes and for cattle. Little if any is used for irrigation, as the quantity from most of the wells is very small. In one or two instances it is reported that the flow has diminished since the well was completed. At Billings, in Yellowstone county, a well about 1,000 feet deep has been drilled, but flowing water was not obtained.

At Dillon, in Beaverhead county, a well has been drilled to the depth of 470 feet, penetrating gravel of a thickness of 250 feet, and below this alternations of clay, sand, and gravel. Several of these latter layers were charged with water, and when drilling ceased the water had risen to within 15 feet of the surface of the ground. This well was made in 1886, at a cost of $4,750.

North of Helena, in Lewis and Clarke county, a well was drilled to the depth of 521 feet, at a cost of $3,130, but without success so far as flowing water was concerned. Water is now pumped by means of a windmill, which, it is estimated, will irrigate an acre of ground. Another well, in Helena, was drilled to the depth of 1,000 feet. This well also does not flow, but water was found at 160 feet from the surface. In Cascade county, near Great Falls, are several deep wells. One of these, at a depth of 160 feet, is reported to discharge at the rate of 6 gallons per minute.

CONDITION OF IRRIGATION IN EACH COUNTY.

NUMBER OF IRRIGATORS, AREA IRRIGATED, FARMS, AND CROPS IN EACH COUNTY IN MONTANA IN 1889.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.	OWNERS OF FARMS. (a)		IRRIGATORS.		Area of counties in acres.	FARM AREA.		Cereals. (Acres.)	Alfalfa. (Acres.)	AREA IRRIGATED.		
				Total number.	Per cent of population.	Per cent of farm owners.	Per cent of population.		Acres.	Per cent improved.			Per cent of area of county.	Per cent of total farm area.	Per cent of land owned by irrigators.
Total	3,706	350,582	95	5,603	4.24	66.14	2.80	92,998,400	1,964,197	46.61	77,162	2,522	0.38	17.85	23.05
Beaverhead	294	42,606	145	385	8.27	76.36	6.32	2,668,000	181,371	53.45	4,745	557	1.59	23.49	25.59
Cascade	73	4,411	60	211	2.41	34.60	0.83	1,664,000	120,988	21.17	1,790	16	0.27	3.65	15.22
Choteau	39	2,834	73	260	5.48	15.00	0.82	17,459,200	65,060	16.57	616	30	0.02	4.36	11.76
Custer	60	4,302	72	393	7.40	15.27	1.13	17,011,200	78,421	25.70	1,124	134	0.03	5.49	30.25
Dawson	12	194	16	68	3.31	17.65	0.58	17,075,200	10,706	25.70	254	....	0.00	1.81	12.58
Deerlodge	470	50,948	108	518	3.42	90.73	3.10	3,254,400	195,002	63.78	11,557	88	1.57	26.13	27.32
Fergus	251	30,401	121	443	12.61	56.66	7.14	4,327,680	166,944	42.25	4,659	30	0.70	18.21	24.76
Gallatin	434	46,901	108	587	9.40	73.94	6.95	1,468,800	200,367	63.52	21,171	233	3.19	23.41	27.72
Jefferson	184	15,105	82	203	3.37	90.64	3.05	1,184,000	69,018	55.24	1,031	14	1.28	21.89	21.13
Lewis and Clarke	231	15,441	67	322	1.66	71.74	1.21	1,664,000	101,321	47.07	2,343	98	0.93	15.24	19.05
Madison	345	36,819	107	387	8.25	89.15	7.35	2,720,000	152,430	58.91	8,074	785	1.35	24.15	27.08
Meagher	260	39,324	151	318	6.70	81.76	5.47	4,480,000	225,980	35.20	7,384	26	0.88	17.40	18.26
Missoula	504	22,404	44	757	5.23	66.58	3.49	11,672,000	155,823	54.87	8,029	115	0.19	14.38	20.03
Park	330	19,735	60	453	6.58	72.85	4.80	3,557,120	167,917	81.22	2,229	156	0.55	11.75	14.77
Silverbow	75	5,968	80	83	0.35	90.36	0.32	585,600	21,626	38.58	397	13	1.02	27.60	29.59
Yellowstone	144	13,180	92	215	10.41	66.98	6.97	1,987,200	51,223	69.66	1,751	227	0.66	25.75	34.88

a Includes owned and hired farms, assuming one farmer to each.

BEAVERHEAD COUNTY is in southwestern Montana, partially inclosed by a loop in the continental divide which bounds the county on the north, west, and south. The altitude is great, the lowest part of the county being nearly 5,000 feet above sea level, while the mountain summits rise to heights of from 10,000 to 11,000 feet. The principal crop, indeed the only important one, is hay, which is grown along the streams wherever water can be brought out upon the land. Irrigation is essential, except in the case of a few small areas wet by the annual overflow of the rivers. The early settlers on entering the valleys of this county found good hay produced in abundance by this natural irrigation along the Beaverhead river and tributary streams. Annually, until 1889, this crop has been good, but in that year of unusual drought the natural hay was almost an entire failure.

The Bighole river rises in the western part of the county and flows northerly, then turns to the east and south, forming in the lower part of its course the northeastern boundary of the county. The discharge of the

Bighole on September 8, 1889, at Melrose, was only 60 second-feet. Along this river and its various tributaries are many stock ranches where hay is raised, but in general the altitude is too great for other crops. In irrigating the hay great quantities of water are used. On many ranches it is customary to turn the water on the fields and let it run for two days or more at one place, and then change to another part of the land, the water finding its way to various portions of the field according to the slope of the ground. By watering the bench land at frequent intervals for a period of about three years, good hay land is made without seeding or plowing. Along the Beaverhead river is a succession of valleys, with broad fertile lands, but with an exceedingly scanty water supply. The uppermost and most southern of these valleys, known as Centennial valley, lies in Madison county. It is about 40 miles long by 2 to 3 miles wide. From this valley Redrock creek flows through a short canyon and enters Redrock valley, about 25 miles long and 2.5 miles wide. North of this comes in turn Beaverhead valley. The creek has been gauged at a point near Redrock, and from these measurements computations of the discharge for 1890 have been made, showing an average flow for the year of 148 second-feet, the minimum being 40 second-feet and the maximum 675 second-feet.

On April 10, 1890, when Redrock creek should have been carrying a considerable volume of water, it was almost dry at a point 6 miles above Redrock, while below a number of springs added a small amount to the stream. At the same time the Horse Prairie and Grasshopper creeks were flowing a small volume, sufficient to add appreciably to the discharge of the Beaverhead. The upper valleys of these and other tributaries of the Beaverhead are in general broad, situated at comparatively low elevations, and containing an amount of arable land so great that there is some question whether the whole area can be irrigated even by storing the water, more especially as the water duty in these valleys is very low on account of the open character of the soil.

The principal towns of the county are along the Beaverhead river, which is formed by the junction of Redrock and Horse Prairie creeks. Along the valleys are many ranches, and although but a small proportion of the land is under crop, yet already there is often a general loss from lack of water. On September 9, 1889, this stream, at Dillon, was flowing at the rate of 75 second-feet. There is an ample supply for the present acreage during the spring and early summer, at the time when the crops need little or no irrigation, but later in the season, when the long continued dry weather prevails and the crops are withering, the streams diminish so that there is not sufficient water for all claimants, as may be inferred by the above measurement. At such times the absence of efficient regulation creates endless litigation and consequent poverty and distress among the farmers, many of whom mortgage their farms in order to raise money to defend their water rights, without which their land is valueless. In the higher valleys alfalfa is reported to be unsuccessful, but timothy, redtop, and other grasses, as well as white clover, oats, wheat, and potatoes, are profitably cultivated.

CASCADE COUNTY is comparatively small, lying along the Missouri river a little to the northeast of the center of the state, and including the lower part of the valley of the Sun river. These rivers flow through broad, high plains or "bench lands," into which they have cut comparatively narrow valleys, which, however, widen in places to a breadth of several miles. Southeast of the Missouri river the county extends to the peaks of the Big Belt and Little Belt mountains, and thus contains many streams convenient for irrigating purposes. The greater part of the irrigation in the county is accomplished from these small streams, the use of the waters of the Missouri river not being always practicable or successful. A small amount of land is cultivated by water from this great river, and this area could be increased enormously by the construction of a large, well planned irrigating canal. The lower lands along the Missouri are overflowed usually in June, and some hay is raised by natural irrigation.

On the bottom lands throughout this county there is usually sufficient moisture to cause grain and vegetables to sprout and attain considerable size, but the latter part of July is generally hot and dry, and all crops then require the artificial application of water at least once. Along the foot of the Belt mountains the country is broken, but the small, narrow bottoms are cultivated by taking the water from the springs or small streams. The principal agricultural areas of the county are in Chestnut valley, a broad opening along the southeastern side of the Missouri, extending down to Smith river, and in the valley of Sun river. The amount of water in this latter stream has been measured at a point about 18 miles above the town of Augusta, being thus above irrigating ditches. Gaugings were begun on August 5, 1889, and continued through 1890, the results showing an average discharge of 715 second-feet for 1890, the minimum being 160 second-feet and the maximum 4,085 second-feet from a drainage area of 1,175 square miles.

DISCHARGE OF SUN RIVER ABOVE AUGUSTA, MONTANA.

(Drainage area, 1,175 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
August 5 to 31	221	200	213	13,100	0.21	0.18
September	260	200	214	12,733	0.20	0.18
October	200	200	200	12,300	0.20	0.17
November	200	180	191	11,364	0.18	0.16
December	....	....	175	10,762	0.17	0.15
1890.						
January	....	....	[a]175	10,760	0.17	0.15
February	....	....	[a]175	9,712	0.15	0.15
March	....	....	[a]175	10,760	0.17	0.15
April	1,580	160	371	22,074	0.35	0.31
May	4,085	1,990	2,804	172,446	2.75	2.18
June	4,000	1,850	2,342	139,349	2.23	1.99
July	2,440	450	961	59,101	0.94	0.81
August	480	315	371	22,816	0.36	0.19
September	365	260	304	18,088	0.29	0.26
October	480	240	315	19,372	0.31	0.27
November	390	275	322	19,160	0.31	0.28
December	340	240	267	16,420	0.26	0.23
Per annum	4,085	160	715	520,058	8.29	0.60

[a] Estimated.

There are several large canals in the Sun river valley, of which the two following may be mentioned: the Sun river ditch takes water from the north side of the Sun river 2 miles above the town of the same name. The ditch is 14 miles long by about 8 feet wide, and it cost approximately $14,000. It is owned by an association of ranchmen, who claim to have a supply ample for all their needs. The annual cost of the water is about 25 cents per acre. The Crown Butte canal takes water from the south side of the Sun river and carries it easterly for about 22 miles. The average width is 19 feet, depth 3.5 feet, and discharge about 200 second-feet, and its cost was about $60,000. It is proposed to construct a system of reservoirs sufficient to supply water during times of scarcity. In the Chestnut valley a canal has been built taking water out on the east side of the Missouri, but it is reported that on account of engineering defects this canal is not entirely successful in delivering a sufficient supply of water, although the amount in the river is many times what is required.

CHOTEAU COUNTY embraces an immense area of elevated plains adjoining the British possessions. It extends from the continental divide eastward over the high plains along and across the Missouri river to Dawson county on the east. Numerous streams issue from the high mountains forming the western border of the county and flow in deep channels easterly down the slope of the plains to join the Missouri. The principal of these rivers are the Marias, Teton, and Sun, the last named forming for a portion of its course the southern boundary of the county. The Missouri river flows into the county from Cascade county on the south, and then pursues a general easterly course. This river, as well as it tributaries, has cut deep into the plain, so that the streams now flow at a depth of several hundred feet below the surface of the country, rendering it exceedingly difficult, if not impossible, to take the water from the main streams out upon the bordering bench lands. Milk river flows easterly through the northern part of the county, receiving waters from the hills and the high plains or bench lands near the border between the United States and the British possessions, and finally emptying into the Missouri river in Dawson county. Between Milk river and the Missouri are short ranges of mountains rising 2,000 feet or more above the plains. The streams flowing in all directions from these mountains have already been used to a small extent for irrigation.

The general altitude of the county is from 3,000 to 4,000 feet, the plains rising rapidly on approaching the mountains, and finally reaching an elevation of nearly 5,000 feet. Cattle range over these great tracts of gently rolling land, finding an abundance of summer feed, for in most years there is sufficient rainfall to insure good forage, and occasionally even to mature a crop of cereals. Without irrigation, however, no crop is safe in this county, and attempts at dry farming result in disaster.

The county is very thinly inhabited, the principal towns being along the Missouri river from Great Falls to Fort Benton or on the Sun and Teton rivers. The northern part of the county has until lately been held as an Indian reservation, and this immense body of agricultural land is being rapidly taken up. In the Milk River valley especially the fertile lands now thrown open offer inducements to settlers. This valley is reported to be 3 miles or more in width, and to possess large areas of rich soil. The water supply is probably not sufficient under present circumstances for the irrigation of more than a small percentage of the land, since the drainage basin of the river embraces but a relatively small area of high mountains and furnishes little water after the early spring freshets, the river becoming almost insignificant in size. At times it is a great torrent overflowing the banks, or appears as an inland lake many miles in width.

On the head waters of the Marias river a little irrigation is practiced, and along the Teton river to the south of this nearly every ranch has an irrigating ditch, all the water being claimed. A measurement of the quantity of water in this stream at Choteau, where the area drained is about 900 square miles, showed on August 7, 1889, only 26 second-feet. A large irrigating system has been projected and a canal partly constructed to take water from this river, and by the use of various storage basins, notably Benton lake, it is proposed to cover almost incredible areas of rich table lands. Along the Sun river, which separates this county from Lewis and Clarke county and then flows through Cascade county, are several large canals which furnish water to lands lying in these counties, but the unregulated flow of the river is not sufficient to fill all these canals during the latter part of the summer and storage systems are projected.

South of the Missouri river are a number of streams which flow from the Highwood and Little Belt mountains to the south. Along all of these streams irrigation has been developed and as much land brought under irrigation as can be supplied in favorable years. In the drought of 1889 and 1890, when the streams were low, large acreages of crops were destroyed, and the farmers report that the value of the crops lost would have paid for storage systems on many of these streams. Along the Missouri, at various points where the land is too high for irrigation by ditches, it has been proposed to lift water by means of pumps driven by windmillls or other means.

CUSTER COUNTY is in the southeastern corner of Montana, adjacent to the Dakotas and Wyoming. On the northwest it extends across the Yellowstone river and to or even over the divide between the drainage of that stream and of the Missouri river, thus including immense tracts of nearly level plains. The general altitude of the agricultural lands is from 2,200 to 4,000 feet, and the temperature is favorable for maturing the cereals. Stock raising is the principal industry, although the large extent of arable lands and the generally favorable character of the water supply promise a great development of agriculture in the future.

The county as a whole lies in the Great Plains region, the nearest large mountains being the Bighorn range to the southwest in Wyoming, and next to these in importance the Black Hills, which lie to the southeast, mainly in South Dakota. Streams from these mountains enter the county on the southern border, the principal of these being the Tongue, Powder, and Little Missouri rivers. The first named, rising in the high mountains and flowing but a short distance before entering the county, furnishes the best perennial supply of water. A number of canals or ditches have been built, the most notable being the canal above Miles city. The bottom lands along the streams are in general narrow and so irregular that long ditches are almost impracticable. The discharge of Tongue river on October 6, 1889, was 200 second-feet, the area drained being 3,785 square miles.

In the valley of the Rosebud, west of the Tongue river, the summer water supply is not sufficient to fill the ditches already constructed, since this stream does not rise in the high mountains. In the valleys east of the Powder river the water supply is irregular, and is in general insufficient during the latter part of the crop season, for on account of the distance from the mountains much of the water disappears before entering the county from the south. Along the Little Missouri, farther to the east, the supply is even more scanty, this river rising in the Black Hills, the altitude of which is not sufficient to cause the water to flow perennially. This valley is thinly settled, and there may be said to be no irrigation carried on at present, the high banks of the stream and the irregularity of the water supply rendering canal construction expensive and a matter to be entered upon with great care. There are excellent storage facilities, and the large extent of arable land and the possibilities of holding flood water will tempt capitalists to construct efficient irrigating systems.

On both sides of the Yellowstone river in the northern part of the county and along the tributaries entering from the north and south are extensive tracts of fertile land adapted for agriculture in every respect save that of moisture. This land is at present used principally for grazing, since crops can not be raised upon it with any certainty without irrigation. There is an ample supply of water in the Yellowstone river, and at many points the fall of the river is sufficient to allow canals to be taken out, covering long stretches of bottom land. The great expense involved has up to the present time deterred the inhabitants and owners of arable land from building canals. Irrigation is carried on in a very small way by utilizing the little streams entering the valleys from the sides and by damming the ravines and holding rain water for short periods. In the valley of the Rosebud and farther down along the Yellowstone, where ditches are too costly for private enterprise, steam pumps have been tried and are reported to be successful in raising water sufficient for small areas. Work of this character, however, has not been carried on for a length of time sufficient to demonstrate the financial success of agriculture under these conditions.

By the construction of canals from the Yellowstone and Tongue rivers a great part of the low lands along these streams can be reclaimed, but it will not be possible to cover in this way all the fertile lands, since the greater part of these lie too high. Some of this latter land can be irrigated by means of storage systems in the higher rolling or hilly country, and in a few instances small storage reservoirs have already been built. Springs and to a small extent artesian wells are used to irrigate gardens and trees in the lower lands. The Miles City ditch now being constructed is the largest irrigation enterprise in this county. It is to take water from the Tongue river and carry it down on the east side of the stream to within about 2 miles of the Yellowstone, where it turns and follows the general course of that stream. Twenty miles have been built, and the total length of the ditch when completed will be 28 miles. The width is 10 feet, the carrying capacity about 60 second-feet, and the cost reported upward of $100,000. The water in the Tongue river is to be raised by a permanent dam 320 feet in length to a height 7 feet above low water.

Dawson county is in the northeastern corner of Montana, adjoining the Dominion of Canada on the north and the state of North Dakota on the east. The two counties of Custer and Dawson occupy the entire eastern end of the state of Montana, and are similar in many respects, both lying within the Great Plains region, and their surface in a general way being level. The Missouri river, which crosses the county from west to east, and the Yellowstone, which flows through the southeastern corner, as well as the tributaries of both of these streams, have carved channels below the general level of the country, so that the surface of the plain, although at a distance apparently level or but slightly undulating, is in reality often rough and broken.

The soil is very fertile, but there is not sufficient rainfall to support grains and vegetables in all seasons. Occasionally small crops of corn, millet, potatoes, and vegetables are obtained without irrigation, especially in the narrow bottom lands along the perennial streams, but these crops can not be depended upon. The greater part of the arable land lies so high that river water can not be taken out upon it, but there are narrow strips of bottom land, especially along the Yellowstone, as in Custer county, to which canals can be built. This river and the Missouri furnish an ample supply of water at all times, the discharge of each probably not falling below 5,000 second-feet. The small streams generally become dry during the summer.

What little irrigation is done in this county is carried on by water from springs, since it has been found too expensive, with the limited means of the present inhabitants, to take water from the large perennial rivers. A larger acreage could be irrigated by individuals by the construction of small storage reservoirs, but comprehensive irrigation systems can only be entered upon by organizations having ample capital. The principal industry is grazing, the greater part of the grain and other farm produce needed by the inhabitants being brought in from other localities. The settlements are mainly in the eastern end of the county along the Yellowstone, where the altitude is 2,000 feet or upward.

Deerlodge county is in western Montana, west of the continental divide, and thus includes a portion of the headwaters of tributaries of Clarke fork of the Columbia. Mining is the principal industry, although agriculture is of rapidly growing importance, as the mining towns furnish good markets for all products. Nothing, however, can be raised without irrigation, and, as in other places where two classes of industry both depend for their success upon the use of water the supply of which is limited, there is often friction between the irrigator and the miner or mill owner. The farmers assert that the powerful corporations needing water for their mills or mines take it in spite of prior rights, or load the streams with débris, filling the ditches or ruining the land, and that it is impossible to secure redress.

The principal agricultural land is in the Deerlodge valley, lying at an altitude of from 4,300 to 5,000 feet, this valley being among the richest and best developed valleys in Montana. It is in all about 40 miles long and from 1 mile to 5 miles wide, having a rich and highly productive soil, but one which contains, especially in the lower lands, considerable alkali, requiring a very careful use of the water to prevent the formation of an alkaline crust upon the surface. Deerlodge creek, which rises in Silverbow county, runs northerly through this valley, and its waters are diverted, especially near the head, by many irrigating ditches. The larger part of the irrigation is done by water from creeks which flow into the Deerlodge valley both from the east and the west. Along each of these streams many ditches are taken out, each ditch supplying water for one or two ranches. In nearly every instance the irrigators state that there is often scarcity of water. They also state that at the head of many of the creeks are small lakes, which probably can be increased in area and capacity, and there are also basins needing only the construction of short dams to be converted into reservoirs. Individuals have already demonstrated the success of storage for irrigation, and there is now a demand for some general system.

Besides the Deerlodge valley, there are several others of importance in agriculture or stock raising. To the west is Flint Creek valley, in which, besides mining, stock raising is an important industry, the most notable crops being those raised for forage. The water is said to be all appropriated, none being available for late settlers, unless possibly by storage. Toward the northern part of the county, on both sides of Nevada creek and the Big Blackfoot, are thousands of acres of good land without water. The water supply of the Big Blackfoot is large, but expensive canals will be required in order to use it to the best advantage. Along these streams and along the Little Blackfoot, which joins Deerlodge creek, are extensive irrigated areas, farming being everywhere successful on account of the markets afforded by mining settlements. The Little Blackfoot valley is over 20 miles long and a mile or more in width, containing extensive areas of fine land, the soil of which is a rich sandy loam, hay, however, being at present the principal crop. The Little Blackfoot river in the latter part of April, 1890, when in flood, was carrying about 150 second-feet.

Fergus county lies nearly in the center of Montana, being between the Missouri and Yellowstone rivers, although not bordering upon either of them. The county extends from the plains region on the east, and includes on the west a part of the first ranges of the Rocky mountains. Its location, therefore, is favorable to the development of agriculture by irrigation, since it contains extensive tracts of farming land immediately adjacent to elevated catchment areas. The county is divided into two topographic basins, that of the Judith river on the northwest and that of the tributaries of the Musselshell on the south and east. The melting snow from the lofty ranges gives rise to many small streams, which finally unite into one or the other of these two drainage systems. The county is comparatively well watered, containing as it does a large number of creeks, each of which can be easily and cheaply used for irrigation. There are thus many small ditches owned by individuals and few, if any, corporations or associations of irrigators.

The drainage basin of the Judith river is partially surrounded by high mountains, upon the slopes of which is excellent summer grazing. Ranchmen have taken up a great part of the land along the streams, and have constructed small irrigating ditches for the purpose of raising winter feed. The majority of the farmers had little means and the ditches were built in the cheapest possible manner as temporary expedients. Greater economy of water would be attained by the construction of one well made canal to take the place of a number of these small ditches. Already on many of the tributaries of the Judith river more ditches have been constructed than can be supplied with water during a part of the crop season, and thus the irrigators on the lower parts of these streams have been unable to obtain sufficient water to save their crops. The discharge of the Judith river itself during the summer is very small, from the fact that many of the mountain streams are evaporated from the sandy channels or are entirely used in irrigation.

Land is still being brought under cultivation by new settlers, although the water rights of the older inhabitants remain unprotected, and apparently a condition of affairs will ensue in which the irrigator at the head waters will be the only one who can be sure of his crops. The snow melts rapidly on the lower summits and flows away in May and June, the streams becoming very small in July and August, so that it will be necessary to store the water which is not needed in the spring for a few weeks only. During years of unusual rainfall crops are raised in the Judith basin without irrigation. For example, in 1887 and 1888 large crops of cereals were raised in a few instances in this manner. In 1889, however, nearly all the crops on unirrigated land were lost, and owing to the scarcity of water in the streams the yield on lands under ditch was in many cases small. In 1890 also the snows were light and the results were disappointing. Many of the ranches were taken up originally after years of abundant rainfall, when the old grass was thick and heavy, and there was every indication that crops could be raised without the artificial application of water. Along the streams which flow east into the Musselshell the conditions are in most respects similar to those prevailing in the Judith basin. Ranches are scattered along the streams, and small ditches have been taken out by the respective owners. There is apparently plenty of water near the foot of the mountains, and at those points grain occasionally matures without irrigation. Farther down the stream, however, there is often not sufficient water for one-half of the ditches constructed.

GALLATIN COUNTY is in southern Montana and covers the drainage basin of the Gallatin river from its head waters in the Yellowstone national park. The county is long and narrow, stretching from the continental divide northerly to the Missouri river, along which it extends for nearly 10 miles. It thus includes in its northern end the Gallatin valley, which at the present time is probably the finest area of agricultural land in the state. This valley, the altitude of which ranges from 4,000 to 5,000 feet, is bounded on the east by the Gallatin and Bridger ranges, from which flow numerous streams to form the East Gallatin river. The main stream, or West Gallatin, traverses the valley, as also does the Madison farther to the west. These, uniting with the Jefferson, which comes in from the southwest, form the Missouri, the junction being known as the Three Forks.

Irrigating ditches and canals are taken from all these streams and also from their tributaries, the water supply being excellent. The smaller streams offer especial facilities for the construction of ditches by individual farmers, so that agriculture has progressed rapidly and successfully along their valleys. In the Gallatin valley itself, and upon the bench lands to the west, the large extent of comparatively level land and the abundant perennial supply of water in the rivers offer inducements for the construction of large irrigating systems. In spite of the magnificent resources of the county, development has not been in all instances satisfactory, from the fact that it has not been governed by efficient and systematic regulations. The first settlers claim that they are being deprived of water by persons who have no legal right to it, but who by their location near the sources of supply are able to readily secure the flow of the stream, while, on the other hand, the owners of secondary rights, who are generally in the majority, accuse the old settlers of taking more than a proper share of the water and employing it in a wasteful manner. Among the foothills in seasons when the ground is kept moist by snow, excellent crops of winter wheat are occasionally raised without irrigation, but crops planted in the spring are not successful in this way, except in the case of some of the old ranches on the lowest grounds along the river, where the soil is kept moist by seepage. The same land has been cultivated year after year without apparent diminution of fertility, although some farmers find that the best results are obtained by letting the fields lie fallow occasionally, as this kills many of the weeds and increases the subsequent crop.

Along the streams which flow into the East Gallatin river are no large canals or corporations selling water, and the ditches are mainly controlled by individuals. In many cases the whole of the water is claimed, and in the drought of 1889 and 1890 large areas of crops were lost. The necessity of reservoiring some of the surplus water was felt and several projects were organized for the purpose of building storage works. The water supply from the West Gallatin, however, was large, and the necessity of water storage along that stream has not been

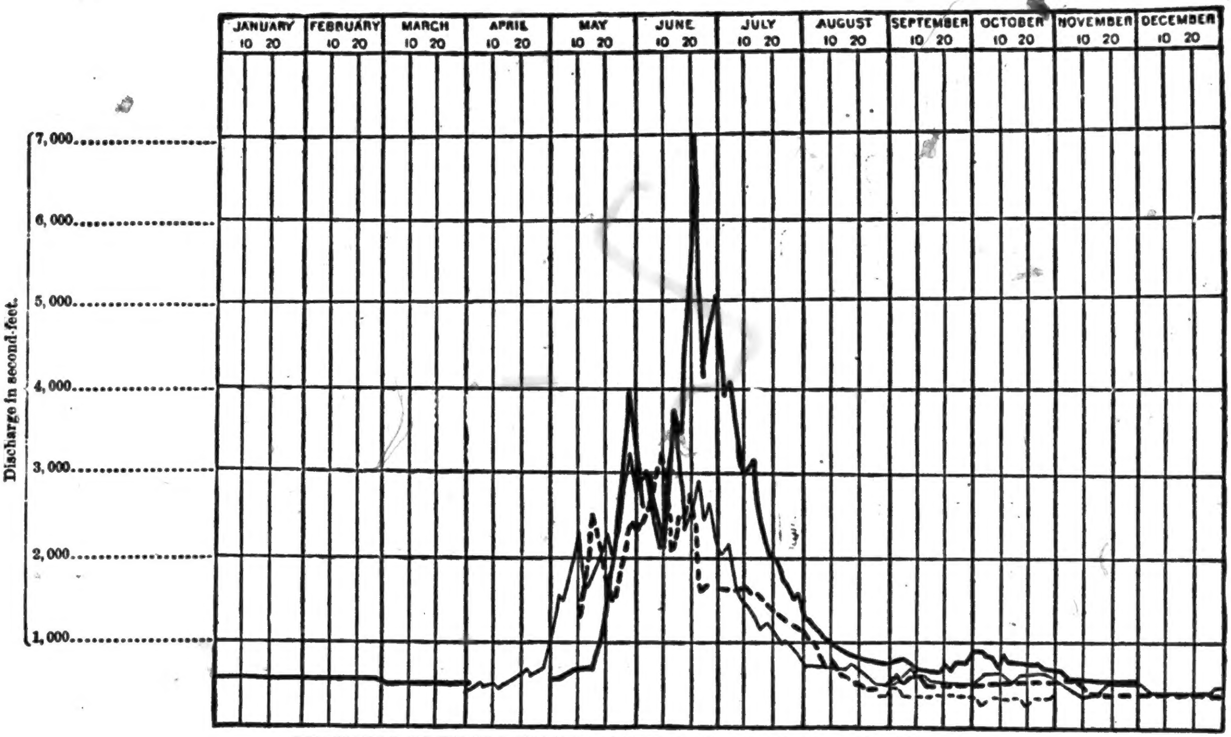
VIEW OF VALLEY AND BENCH LANDS ALONG WEST GALLATIN RIVER, GALLATIN COUNTY, MONTANA.

apparent. Measurements of the discharge of West Gallatin river were made at a point (a) in the mouth of the canyon a few hundred feet below Spanish creek, this being about 20 miles southwesterly from Bozeman.

---

[a] In the diagram the discharge for 1889 is indicated by the lighter broken line, that for 1890 by the lighter continuous line, that for 1891 by the heavier broken line, and that for 1892 by the heavier continuous line. The results obtained are shown in the table following:

DIAGRAM OF DAILY DISCHARGE OF WEST GALLATIN RIVER BELOW SPANISH CREEK, GALLATIN COUNTY, MONTANA.



DISCHARGE OF WEST GALLATIN RIVER, NEAR BOZEMAN, MONTANA.

(Drainage area, 850 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
August 16 to 31..	437	402	426	26,200	0.58	0.50
September	640	402	450	26,775	0.59	0.53
October..........	437	367	402	24,723	0.54	0.47
November	....	....	400	23,800	0.52	0.47
December	....	....	400	24,600	0.54	0.47
1890.						
January	....	....	320	19,680	0.43	0.38
February	....	....	320	17,760	0.39	0.38
March 23 to 31 ...	320	320	320	19,680	0.43	0.38
April............	1,255	280	460	27,370	0.60	0.54
May	3,195	1,300	2,092	128,658	2.84	2.46
June.............	3,800	2,060	2,641	157,139	3.47	3.11
July	2,165	890	1,388	85,362	1.88	1.63
August...........	890	570	761	46,801	1.03	0.89
September	690	570	607	36,112	0.80	0.72
October..........	650	570	501	36,346	0.80	0.70
November	570	430	506	30,107	0.66	0.60
December........	....	....	450	27,675	0.61	0.54
Per annum..	3,800	280	871	632,690	13.94	1.03
1891.						
January	....	....	400	24,600	0.54	0.47
February	....	....	400	22,200	0.47	0.47
March	....	....	450	27,675	0.61	0.53
April	....	....	500	29,750	0.65	0.59
May 6 to 31	2,535	1,390	1,897	116,665	2.57	2.23
June.............	2,975	1,615	2,516	149,702	3.30	2.95
July	1,760	1,090	1,534	94,341	2.06	1.81
August..........	1,050	570	761	46,801	1.03	0.90
September	650	570	583	34,688	0.77	0.69
October.........	610	570	587	36,100	0.80	0.69
November	570	370	501	29,809	0.66	0.59
December.......	500	430	434	26,691	0.59	0.51
Per annum..	2,975	370	880	639,022	14.05	1.03
1892.						
January	430	430	430	26,445	0.59	0.51
February	430	400	429	24,667	0.55	0.50
March 1 to 19 ...	400	400	400	24,600	0.54	0.47
April...........	....	....	*450	26,775	0.59	0.53
May	4,065	465	1,488	91,512	2.02	1.75
June............	6,800	2,270	4,163	247,698	5.48	4.90
July	5,170	1,300	2,544	156,456	3.46	3.00
August..........	1,300	810	957	58,855	1.30	1.12
September	850	650	734	43,673	0.97	0.86
October.........	890	650	743	45,694	1.01	0.87
November	650	570	589	35,045	0.77	0.69
December.......	570	500	549	33,763	0.74	0.64
Per annum..	6,800	400	1,123	815,183	18.02	1.32

* Estimated.

A large number of ditches and several canals of notable size depend upon the West Gallatin for their water supply. The more important of these are the works of the Gallatin Canal Company, the West Gallatin Irrigation Company, and the Excelsior Canal Company. The West Gallatin canal heads at a point about 3 miles above Salesville and following the contours, which are exceedingly irregular, gradually leaves the river and finally turns toward the west, covering lands from 10 to 15 miles west of Bozeman. The length is about 24 miles and the width varies from 24 feet on bottom near the head to 14 feet on bottom near the end. Along the course are several flumes and one tunnel through the spur of a hill.

The Gallatin canal heads on the east side of the river at a point about 2 miles below Spanish creek and carries the water out northeasterly toward Bozeman. The length of this canal is about 22 miles, its width 20 feet, and its ordinary carrying capacity from 75 to 100 second-feet and upward. The water is rented at the rate of $2 per miner's inch from June 10 to September 1, and it is estimated on the part of the company that 1 miner's inch will furnish water for 2 acres of small grain. A second canal, to cover some of the lands under this canal, has lately been built by farmers who thought they could secure a cheaper and more efficient supply from a source owned and controlled by themselves. This latter canal is about 12 miles long, 18 feet wide, and was begun in October, 1890, with the intention of using water in the succeeding year.

Along the Madison are many ditches, covering mainly the lower lands. On the very lowest ground along the stream a little hay is cut on land not irrigated. On Willow creek and on the Jefferson bottoms are many ditches, but there is no comprehensive system of irrigation, and in the Willow Creek valley there is reported to be need of more water. In the extreme western end of the county are several canals taking water from the Jefferson river. Of these the Lower and Upper Jefferson ditches may be mentioned, aggregating in all over 30 miles of main, lateral, and distributing ditches.

Water is used from the latter part of April or the early part of May until October. The duty of the water is reported to be very low, one reason being that the ground watered has mainly been newly broken and more water is required than on land irrigated for several years. It is found that after the water has been used for a few years the subsoil becomes more compact and a smaller quantity of water will cover the same area of ground. At the same time the ditches become silted and do not lose so much water by seepage. As it is at present the ditch probably delivers only about two-thirds of the quantity taken in at the head, but after allowing for this loss the irrigated ground during the season is probably covered to an aggregate depth of 24 inches, giving a water duty of 2 acre-feet per acre. Between the Gallatin and Madison rivers is an extensive bench land of great fertility, which has afforded for years a most tempting opportunity for irrigation enterprise. The general elevation, however, is great, and the edges of the bench are deeply eroded, so that canal construction is expensive. By the employment of sufficient capital the engineering difficulties have already been to a large degree surmounted, but the greater part of the bench land, which is considered to be equal if not superior to the lower grounds, has not been touched on account of the expense of bringing water upon it.

JEFFERSON COUNTY lies northwest of Gallatin county on the west side of the Missouri river, occupying a comparatively small area between it and the continental divide. On the south the county is bounded by the Jefferson river, one of the three great tributaries of the Missouri. The principal agricultural land is along the Jefferson and Missouri rivers, and in the valleys of the small tributaries which flow into these from the north and west. These lands are from 4,000 to 5,000 feet in altitude, and, especially along the large rivers, they have a climate favorable for the production of vegetables and fruits. Nothing is grown without irrigation, but the main dependence for water is not upon the large rivers, but upon the small mountain streams that flow from the high peaks of the divide. In a few instances water has been taken from the Jefferson and the Missouri, but the ditches are small and cover only the lowest land, much of which is wet by the annual overflow. It is probable that a large canal system could be built, taking water from the Jefferson and carrying it to some of the higher bench lands. Owing to the prevailing drought and the scarcity of feed on the ranges the stock industry has rapidly decreased in value, the cattle having been driven to other parts of the state. Agriculture, wherever water is to be had, is prosperous, largely due on account of the nearness of Helena, Butte, and other mining towns.

LEWIS AND CLARKE COUNTY is north of Jefferson county and lies east of the continental divide, occupying a comparatively narrow strip of country extending from the summits easterly toward and on the south to the Missouri river, which flows in a general northerly direction along the continental divide and from 10 to 30 miles to the east of it. At about the center of the county the stream turns to the northeast, flowing through Cascade county, while the continental divide turns off toward the northwest nearly at right angles to the river, thus rapidly increasing the distance between the mountains and the streams, allowing space for the high plains to sweep around toward the south and rendering the tributaries of the Missouri longer. For example, beginning at the extreme north, in Choteau county, the Marias river is 150 or more miles in length and traverses a great width of the high plains. The Teton, south of this, is shorter, and to the south, in turn, the Sun river, which forms a portion of the northern boundary of the county, is still shorter and traverses a less width of plain, but its length is far greater than that of the Dearborn, still farther to the south, and the last river of the series. South of this are many important streams, but their course is so brief that they are known as creeks.

This comparatively narrow county, mainly a foothill region, is favorably situated for the development of irrigation. Along the western border are mountains, furnishing water for numerous streams, which, flowing toward the east, are soon lost in the Missouri. Each of these streams as it issues from its canyon is used for irrigation, the water being easily taken out upon the narrow bottom lands by means of small private ditches, the low water supply in general being used to such an extent that there is little, if any, water left in times of scarcity for the wider valleys to the east, nearer the Missouri. Along the Sun river several canals have been built taking water to lands in this county and to those in Cascade and Choteau counties.

Along the Dearborn river are a number of ditches and one notable canal system diverting the waters of the north fork of the river before they leave the canyon. This is done by means of a dam of rock filled crib work bedded on the solid rock. The canal carries water a distance of 4.5 miles to Flat creek, down the channel of which it continues for 20 miles, covering, it is estimated, in this course over 20,000 acres of land, laterals being taken directly from the creek, the topography of the country being peculiarly favorable. Besides these laterals, other canals are taken from Flat creek, and are to be extended to cover the vast areas of arable lands lying in the direction of Great Falls. Suitable storage sites are to be utilized in order to insure permanence of supply. The annual charge for water is reported to be $1 per acre.

Besides the irrigation from these rivers and the creeks farther south, some land is watered by springs which issue among the foothills or in the lower valleys. There is an ample supply of water near the mountains, for here the arable land is limited in extent and the available water is at a maximum. Irrigation, however, is making such rapid development that it seems probable that before long a scarcity must ensue even in the most favored spots. As the ranges are fenced in the stock men are compelled to raise more and more feed for their cattle, thus greatly increasing the area of lands cropped. During the drought of 1889 and 1890 most of the irrigators suffered for lack of water, as the area of land under cultivation in many of the valleys was in excess of the available water. Under this condition of affairs it has often been found practicable to raise crops by securing a thorough saturation of the soil late in the fall or in the early spring, at times when the demand for water is less than in the crop season. The ranchmen living along the foothills south of the Sun river realize that the only way in which the small level areas in this broken and hilly country can be reclaimed is by storing the water of small streams or "dry creeks", as they are usually called, since they do not carry any water in summer. Several instances are reported where small storage reservoirs have been constructed and sufficient water has been saved to irrigate several ranches.

Besides the large valleys along the Sun and Dearborn rivers there is in the southern part of the county a broad, fertile plain known as the Prickly Pear valley. The western side of this area is well cultivated, but there are thousands of acres of good land to the west for which there is at present no water supply. Helena, the capital of the state, is on the southwestern edge of this open country. The irrigating ditches are all small, being owned principally by individuals. Good crops have sometimes been raised here without the application of water. The Missouri river is unfortunately too far below the general level to furnish any water from its abundant supply, but it is possible that some of its tributaries farther to the southwest may be diverted to cover a portion of this area.

The Missouri river has been measured at points within this county, the earliest series of gaugings being at Canyon Ferry, about 18 miles east of Helena. This location, however, was not found favorable and gaugings were continued at a point farther down the river, this being at Craig, about 30 miles north of Helena. Dearborn river was measured August 9, 1889, at Dearborn, where the drainage area is 350 square miles, and the discharge found to be 47 second-feet. A later measurement, on April 15, following, showed 37 second-feet. (*a*)

---

[a] The results of the measurements are shown in the following tables:

DISCHARGE OF MISSOURI RIVER AT CANYON FERRY, MONTANA.

(Drainage area, 15,036 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
September	2,040	1,693	1,873	111,443	0.15	0.12
October	2,516	2,040	2,230	137,145	0.18	0.15
November	2,834	2,230	2,502	148,869	0.20	0.17

Madison county is in the southwestern part of Montana, between Beaverhead and Gallatin counties. It extends from the continental divide on the south to the Jefferson river on the north, and includes the greater part of the course of the Madison river as well as a portion of that of the Jefferson. Between the high mountain ranges, which rise to elevations of 10,000 feet or over, are several broad valleys containing a large amount of excellent arable land, and supplied with water from the almost innumerable streams issuing from the different ranges. In these valleys agriculture has progressed rapidly by the aid of irrigation, the mountain streams being well distributed and so located that individual farmers can easily dig ditches and bring the water upon their land. The Madison valley, lying in the western part of the county, is over 30 miles in length and in places 8 miles or over in width. The river of the same name flows northerly through the valley, carrying a considerable amount of water at all seasons of the year. The expense, however, of diverting water from this large river has been so great that individuals have in general been compelled to take water from the side streams, leaving the greater part of the water untouched. The construction of large canals on each side of this river may bring under irrigation enormous areas of the best land in the valley. The water supply of the valley is in general good, and compared with other parts of the county the complaints of scarcity of water are few.

The Madison river has been measured at a point near Red Bluff, the gauging station being below the mouth of Hot Spring creek, at Hayward bridge. (*a*)

DISCHARGE OF MISSOURI RIVER AT CRAIG, MONTANA.

(Drainage area, 17,615 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1890.						
January	....	....	*3,000	184,500	0.20	0.17
February	....	....	*3,000	166,500	0.18	0.17
March	....	....	*3,000	184,500	0.20	0.17
April 17 to 30	6,100	3,595	4,662	277,389	0.29	0.26
May	12,500	6,900	10,472	644,000	0.68	0.50
June	11,900	8,100	10,074	599,401	0.64	0.57
July	7,800	2,614	5,020	308,730	0.33	0.28
August	2,505	1,960	2,216	136,284	0.15	0.13
September	2,306	1,960	2,232	132,804	0.14	0.13
October	2,722	1,742	2,379	146,308	0.16	0.13
November	3,159	2,723	2,868	170,646	0.18	0.16
December	3,159	1,742	2,763	169,924	0.18	0.16
Per annum	12,500	1,742	4,307	3,121,016	3.33	0.24
1891.						
January	3,823	1,742	2,967	182,470	0.19	0.17
February	....	....	3,500	215,250	0.24	0.20
March	....	....	4,000	246,000	0.26	0.23
April	9,130	4,576	5,794	344,743	0.37	0.32
May	12,050	7,150	9,015	554,422	0.59	0.51
June	16,355	11,000	13,645	811,877	0.85	0.77
July	12,960	5,890	9,115	560,572	0.60	0.52
August	5,890	2,832	4,415	271,522	0.20	0.25
September	3,704	2,614	3,078	183,141	0.19	0.17
October	3,704	3,159	3,511	215,926	0.23	0.20
November	4,358	3,486	3,802	226,219	0.25	0.22
December	....	....	3,200	196,800	0.21	0.18
Per annum	16,355	1,742	5,503	4,008,942	4.27	0.31
1892.						
January	....	....	3,000	184,500	0.20	0.17
February	....	....	3,000	172,500	0.18	0.17
March	....	....	3,200	196,800	0.21	0.18
April	4,140	3,268	3,552	211,344	0.23	0.20
May	18,550	3,486	8,004	492,246	0.52	0.45
June 1 to 25	28,650	13,270	21,027	1,251,106	1.34	1.19

* Estimated.

[a] The results of the computations of discharge are shown in the following table:

DISCHARGE OF MADISON RIVER AT RED BLUFF, MONTANA.

(Drainage area, 2,085 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1890.						
January	....	....	1,200	73,800	0.66	0.58
February	....	....	1,200	66,600	0.60	0.58
March	....	....	1,200	73,800	0.66	0.58
April 4 to 30	2,580	1,370	1,620	96,390	0.87	0.78
May	6,420	3,060	4,823	296,614	2.67	2.32
June	6,360	3,780	4,977	296,131	2.66	2.38
July	3,660	1,715	2,518	154,857	1.39	1.21
August	1,640	1,375	1,535	94,462	0.85	0.74
September	1,580	1,420	1,466	87,250	0.78	0.70
October	1,520	1,420	1,498	92,125	0.83	0.72
November	1,470	1,285	1,380	82,110	0.74	0.66
December	1,520	1,285	1,400	86,100	0.77	0.67
Per annum	6,420	1,200	2,068	1,500,239	13.48	0.99

West of the Madison valley the county extends over the Jefferson and Ruby ranges, thus including the Ruby valley and a portion of the Jefferson valley along the Beaverhead and Bighole rivers as well as along the Jefferson river itself. The supply of water in these valleys is not as good as that in the Madison valley, and there are many statements to the effect that although there was ample water when the valley was first settled, yet with the gradual increase of land under irrigation, especially along the head waters, the irrigators in these lower valleys suffer loss of crops. The Bighole river, having a smaller area of cultivated land along its banks, has a large discharge throughout the year, but the Beaverhead diminishes rapidly during the summer, and in 1889 and 1890 was dry in various places. The Ruby river flows continuously throughout the year, and it is reported that all the ranches depending upon it for water have sufficient for their requirements, but the tributaries occasionally shrink far below the needs of the irrigators, and even become completely dry. On September 4, 1889, the stream at Laurin was discharging at the rate of 90 second-feet, the drainage area at this point being 710 square miles. The Ruby valley ditch may be given as an example of irrigation development. This ditch is 8 miles long, 9 feet wide, and 1.5 feet deep, and cost about $5,000. It takes water from the Ruby river by a temporary brush dam about 2 miles above Laurin and carries it down the east side of the valley. The water, as is usually the case, is divided equally among the partners owning the ditch.

The lowest bottom land in these valleys is generally devoted to raising hay, dependence being placed upon the annual overflow of the river. Other bottom lands a little above the reach of the river water are also irrigated for hay, while the bench lands, wherever the water can be brought upon them, are generally sown with alfalfa and grain. The irrigated area is rapidly increasing, settlers pushing up into the higher parts of the valley, while at the same time the older farmers are tilling new fields and gradually enlarging the old ditches. Water is used in general very freely, the quantity varying largely with the character of the soil, the season, and the experience of the irrigator.

Irrigation does not usually begin until the crops are well advanced, but in 1890 the season was so dry that in many places it was necessary to irrigate in order to plow the land, and water had to be applied throughout the season instead of but once or twice, as is usually the case. It sometimes happens that in wet seasons no irrigation is necessary for the first crop of alfalfa. The experience of the farmer counts for a great deal, and even in a dry season losses could often be avoided by the exercise of greater skill and judgment. For example, some of the crops failed because of delay in irrigation, while others were saved by the thorough soaking given to the ground at the time water was plentiful. The presence or absence of alkaline salts, especially on the lowest ground, is a matter of great importance. There are several places in this county where before ditches were made there was no sign of alkali, but upon irrigation the salt rapidly developed upon the surface, requiring years of patience before the farmers could wash it out. In this county are many excellent sites for reservoirs in which the flood water of the spring could be held. The site most frequently mentioned is that at Redrock lake, in the southern end of the county near the continental divide. The water from this lake flows easterly into Beaverhead county, and along its course down Redrock creek and Beaverhead river there is urgent demand for it, since during the late summer the creek is often dry.

MEAGHER COUNTY is near the center of the state, and includes the area from the Missouri river on the west to the summits of the Little Belt and Snowy mountains on the east. There are three independent drainage basins in this county, namely, the head waters of the Smith river, which rises in the center of the county and flows

DISCHARGE OF MADISON RIVER AT RED BLUFF, MONTANA—Continued.

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.		MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.		Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1891.							1892.						
January	1,580	1,240	1,406	86,460	0.78	0.67	January	1,375	1,240	1,305	80,257	0.72	0.63
February	1,580	1,265	1,436	79,698	0.72	0.69	February	1,640	1,330	1,504	86,480	0.78	0.72
March	1,790	1,470	1,631	100,306	0.90	0.78	March	1,640	1,330	1,488	91,512	0.82	0.71
April	1,960	1,640	1,774	105,530	0.95	0.85	April	1,420	1,240	1,295	77,052	0.69	0.62
May	4,260	1,790	3,389	208,423	1.88	1.62	May	2,580	1,330	1,454	89,421	0.81	0.70
June	4,620	3,780	4,167	247,936	2.20	2.00	June	5,940	2,820	4,900	291,550	2.62	2.35
July	3,660	1,155	2,045	125,767	1.13	0.98	July	5,340	1,790	3,225	198,337	1.78	1.55
August	1,640	1,200	1,429	87,883	0.80	0.68	August	1,885	1,285	1,519	93,418	0.84	0.73
September	1,375	1,240	1,309	77,885	0.70	0.63	September	1,420	1,330	1,300	80,920	0.73	0.65
October	1,470	1,240	1,351	83,086	0.75	0.65	October	1,420	1,285	1,327	81,610	0.74	0.64
November	1,470	1,285	1,403	83,300	0.75	0.67	November	1,420	1,330	1,424	84,728	0.76	0.68
December	1,240	1,070	1,137	69,925	0.63	0.55	December	1,420	1,240	1,324	81,426	0.73	0.64
Per annum	4,620	1,070	1,872	1,356,208	12.19	0.90	Per annum	5,940	1,240	1,844	1,336,711	12.02	0.89

northerly through Cascade county into the Missouri; those of the Musselshell, which flows in a general easterly direction, and, third, the so-called Missouri valley on the west. Each of these divisions is bounded by high mountains, and thus the water supply is large, each stream supplying many ditches, owned as a rule by individual ranchmen.

The Musselshell and Smith rivers rise on opposite sides of the Elk mountains, being separated on the north by a comparatively low pass. Agriculture has developed along the narrow valleys to such an extent that most of the available water is used, although a far larger acreage could be covered by a more systematic and economical distribution of the water. In the valley of the Musselshell the greater part of the bottom land is covered by private ditches, and is used to the extent of the water supply. At Martindale on August 17, 1889, the north fork of the Musselshell was discharging 15 second-feet and the south fork 10 second-feet. The higher bench lands are broken, but there are large areas that with a more abundant water supply could be brought under irrigation. On Smith river there is ample water in the higher valleys, but the land below is not so well supplied. The amount of water in the river itself, especially where it enters Cascade county, is usually very small, owing to the diversions made farther up the stream, so that irrigators in Cascade county are interested in securing water conservation, being often in controversy with their neighbors.

The Missouri valley contains the principal agricultural land of the county. The Missouri river leaves a canyon above Toston, the valley widening to a breadth of from 1 mile to 8 miles and extending in all a distance of about 25 miles. Along this course the river has in places cut bottoms from 1 mile to 2 miles in width, above which is the bench land, which in turn gradually disappears into the foothills of the Big Belt mountains to the east. From these mountains come many streams, each of which has eroded a deep and wide notch or coulee into the bench, in many cases forming bottoms of a width sufficient for cultivation. In these the water flows in abundance during the spring and early summer, but it declines or even disappears in July and August. Most of the irrigation is done by means of water from these creeks, for the Missouri river, although carrying a great quantity of water, is relatively at too low a level for the irrigation of much of the best land. It is possible that in the future a large canal may be taken from this river at a point in the canyon above Toston and carried out around the eastern edge of the valley, bringing an enormous acreage under irrigation. If this were done, the waters of the numerous side streams, if properly held in reservoirs, would be available for the lands lying above the level of such a canal. As it now is, throughout the county and in fact the entire state the waters of the creeks are often claimed by the farmers occupying the lower grounds far away from the mountains.

MISSOULA COUNTY lies in the extreme western end of the state beyond the main divide of the Rocky mountains, and contains the greater part of the drainage area of Clarke fork of the Columbia river. On its northeastern corner the county extends over the continental divide and includes a long, narrow area on the head waters of the Marias river, which flows into the Missouri. The northwestern part is traversed by the Kootenai, a tributary of the Columbia. In the northern end of the county there is usually sufficient rainfall for agricultural purposes, and irrigation has been practiced only to a small extent. In the southern valleys, however, its necessity and benefits have long been recognized. The principal areas of tilled land are in the southern part of the county in the valley along the Bitterroot river, which flows northward into the Missoula, the chief tributary of Clarke fork of the Columbia. The Bitterroot valley is over 50 miles in length and from 4 to 12 miles in width, with a large extent of arable land on both sides of the river. The land lying on the left or western side of the stream is well watered by the numerous creeks that flow from the Bitterroot range, which forms the boundary between Montana and Idaho, but on the eastern side the supply is less abundant.

The tilled land in the Bitterroot valley is mainly irrigated in a somewhat primitive manner by small ditches constructed by individual ranchmen or by a partnership of neighboring irrigators. These ditches lead from the mountain streams, and in a few cases, mainly on the east side, from the Bitterroot river itself. The irrigated land is on the bottoms along the streams, the bench lands back from the river being, as a rule, still untouched. By the construction of a large canal taking water from the Bitterroot near the head of the valley and following down near the foothills a very large area of bottom land, and perhaps some of the level lands, could be brought under irrigation. The altitude of the lands of this valley is from 3,200 to 4,000 feet, and the valley being sheltered by high ranges of mountains the climate is mild, being perhaps the most favorable in Montana for the cultivation of fruit. The agricultural land also possesses the advantage of having a ready market for produce at the mining towns in the adjoining counties. The water supply being in general ample large quantities are usually employed and the water duty is correspondingly low. Much of the lower land is gravelly and conducts the water away readily, so that a strong flow of water is necessary in order to irrigate successfully. By the application of plenty of water, however, the apparently worthless gravel bars along the Bitterroot river have been made to yield as high as 5 tons of alfalfa to the acre. During the spring floods the lower lands are in part submerged or saturated by seepage from the river, so that forage crops are successful without any further watering.

One of the largest irrigating canals in this valley is the Republican ditch, which takes water from the Bitterroot about 11 miles above Corvallis and a short distance below the mouth of Weeping Child creek, carrying it down on the east side of the valley to Hamilton and Corvallis, crossing Skalkaho creek on the way. The total length of the main ditch is reported to be 14 miles, its width 12 feet, narrowing to 6 feet at the end, and its cost $16,000. A number of other canals, some of large size, have been projected, the valley offering apparently an excellent opportunity for investment on account of a large area of arable land and the facilities for obtaining water by the expenditure of a reasonable amount of capital. Several storage schemes have also been discussed, as there are excellent opportunities for holding the excess water of the spring in lakes or basins at the head of many of the small creeks whose summer supply is insufficient for the land now under ditch.

In the upper course of the Bitterroot above the main valley are a number of ranches, but here the arable land is limited and the water supply so great as to be in excess of all demands. On Rock creek, east of the Bitterroot valley, similar conditions prevail. There grazing is the principal industry, as there is little farming land, and the altitude is too great for many crops. Northwesterly from the Bitterroot valley down along the Missoula river are several open valleys, but in these irrigation is practiced only to a small extent on account of the expense of diverting water from the main stream. Crops can often be raised without the application of water, but during the drought of the past few years nearly everything has failed. The same conditions prevail farther down the river on Clarke fork of the Columbia, which is formed by the junction of the Missoula and Flathead rivers. For example, at Horse Plains are extensive areas on which good crops are occasionally raised, but the expense of taking water from the river is too great for the ranchmen. Some of the low-lying land along Clarke fork is wet by the annual overflow of the river, this being known among the inhabitants as subirrigation, and from the results following this occurrence the farmers are led to believe in the great benefit to be derived from a thorough system of irrigation.

The Flathead Indian reservation occupies a large part of the center of this county, including the lower part of Flathead lake and also the lands along the river draining the lake. Irrigation is practiced to a small extent by the Indians through the influence of the Jesuits, who have established missions among them. North of Flathead lake and beyond the reservation is an extensive area of excellent agricultural land along Ashley, Stillwater, and Clearwater creeks and Flathead river. Here crops of all kinds, wheat, oats, vegetables, and fruits, have been raised without irrigation, this method of agriculture, however being practiced to a small extent. In the droughts of 1889 and 1890, moreover, the crops were small in amount, in some cases being entirely lost, so that the farmers had their attention forcibly called to the advantages of a good water supply. Irrigation can probably be cheaply developed, as the rivers and tributaries carry a large amount of water throughout the year.

PARK COUNTY is in southern Montana, north of the Yellowstone national park, and receives a great part of the drainage of that elevated, mountainous region. The county itself contains many high mountain ranges, and is thus well watered, the available supply being in many cases in excess of the land to be irrigated. In the southern part of the county are the Beartooth and Snowy mountains, rising to heights of over 10,000 feet, being continuations of the great Absaroka range, from which comes the abundant water supply of the valleys to the south, in Bighorn county, Wyoming. The Yellowstone river, flowing northerly from the national park, passes through the wonderful canyons for which the river is famed and enters the county at its southern border. Here the canyon walls begin to retreat, leaving a narrow strip of lowland which in places widens out to a breadth of half a mile or more. About 25 miles beyond the county line the valley opens still wider, and the river for 35 miles is bordered by open land from 1 mile to 2 miles or more in width. Along this portion of the stream are several towns, depending mainly upon stock raising and agriculture. North of this open country the river plunges through what is known as the Lower canyon, emerging again into a comparatively wide valley, at the head of which is Livingston. Beyond this point the stream continues with rapid fall through narrow valleys, and is bounded usually by high bench lands, the remnants of the plain into which the river has cut its broad channel. The quantity of water in the Yellowstone has been measured at Horr, about 4 miles below Cinnabar, being thus above points of diversion. (*a*)

---

a The results are shown in the following table. In the diagram the discharge for 1889 is indicated by the lighter broken line, that for 1890 by the lighter continuous line, that for 1891 by the heavier broken line, and that for 1892 by the heavier continuous line.

DISCHARGE OF YELLOWSTONE RIVER AT HORR, MONTANA.

(Drainage area, 2,700 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
August 12 to 31.	1,853	1,411	1,660	102,090	0.71	0.62
September	1,653	1,126	1,270	75,565	0.52	0.47
October	1,126	841	976	60,024	0.42	0.36
November	841	651	743	44,208	0.31	0.27
December			*650	39,975	0.28	0.24

* Estimated.

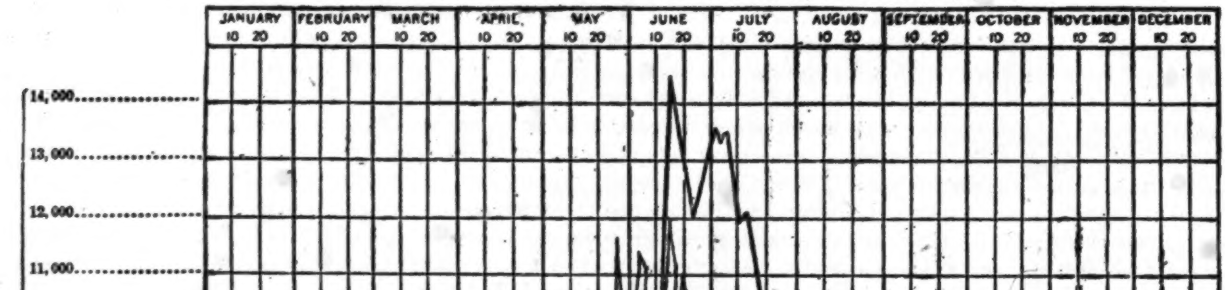
The agricultural lands along the Yellowstone and its larger tributaries receive their water from the smaller streams which issue from the high mountains on both sides. In general the water supply on the east side is better

DISCHARGE OF YELLOWSTONE RIVER AT HORR, MONTANA—Continued.

MONTHS.	Discharge in second-feet.			Total for month in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1890.						
January	....	....	*550	33.825	0.23	0.20
February	....	....	*550	30,525	0.21	0.20
March 23 to 31	620	560	585	35,977	0.25	0.22
April	4,495	510	1,417	84,311	0.59	0.53
May	11,915	5,090	7,522	462,608	3.21	2.79
June	11,915	8,720	10,066	600,117	4.17	3.74
July	9,410	5,760	7,682	472,443	3.28	2.84
August	5,600	3,145	4,375	269,065	1.87	1.62
September	3,145	1,670	2,276	135,422	0.94	0.84
October	1,920	1,160	1,473	90,589	0.63	0.55
November	1,160	850	970	57,715	0.40	0.36
December	815	590	695	42,742	0.30	0.26
Per annum	11,915	510	3,181	2,315,334	16.08	1.18
1891.						
January	590	470	488	30,012	0.21	0.18
February	....	....	*500	27,750	0.19	0.18
March	360	285	316	19,434	0.13	0.12
April	2,720	360	1,082	64,379	0.45	0.40
May	7,480	1,855	5,227	321,460	2.24	1.93
June	8,975	6,685	7,592	451,724	3.13	2.81
July	7,110	5,090	6,135	377,302	2.62	2.27
August	4,920	2,060	3,442	211,683	1.47	1.28
September	2,625	1,250	1,641	97,639	0.68	0.61
October	1,610	1,080	1,264	77,736	0.54	0.47
November	1,080	680	891	53,014	0.37	0.33
December	745	360	475	29,212	0.21	0.18
Per annum	8,975	285	2,421	1,761,345	12.24	0.90
1892.						
January	....	....	*500	30,750	0.21	0.19
February	650	470	570	32,775	0.23	0.21
March	780	620	713	43,849	0.30	0.26
April	780	590	664	39,508	0.27	0.25
May	10,200	710	3,544	217,956	1.51	1.31
June	15,200	6,520	11,201	666,460	4.63	4.15
July	15,500	6,770	10,180	626,070	4.35	3.78
August	6,770	3,400	4,931	303,257	2.10	1.82
September	3,485	1,920	2,808	167,076	1.16	1.04
October	1,920	1,200	1,555	95.632	0.66	0.58
November	1,200	745	952	56,644	0.39	0.35
December	....	....	*800	49,200	0.34	0.30
Per annum	15,500	470	3,202	2,329,177	16.15	1.19

* Estimated.

DIAGRAM OF DAILY DISCHARGE OF YELLOWSTONE RIVER AT HORR, PARK COUNTY, MONTANA.



than that on the left or western bank, from the fact that on the former side the mountains are higher and are often covered with snow throughout the summer. In the valleys close to the mountains an occasional crop can be raised without irrigation. For example, fall wheat in a favorable season has been successful without the artificial application of water. A few ditches have been taken from the river to cover the lower lands, but the expense of maintaining them is often great. They have, however, plenty of water at all times, which is more than can be said of some of the other ditches.

In the larger valleys the water has already been filed upon to such an extent that the amount claimed far exceeds the total discharge of the streams, and the farmers fear that the ditches now under construction can not obtain sufficient water without taking what is now used or demanded by prior appropriators. The Yellowstone river itself carries more than enough water to irrigate all the agricultural land along its course, but unfortunately the level of the water in the river is too low to cover much of the best land, or the expense of building canals has been found upon survey to be so great as to be prohibitory for single individuals or even associations of irrigators, and thus attention has been confined to the smaller streams, leaving untouched vast tracts of fertile land to which in the future the river water may be brought.

The soil on the benches, while in general of excellent character, is occasionally very thin, appearing on the surface to be composed wholly of gravel. One case is cited on good authority in which the general level of the soil on the first thorough saturation was reduced from 1 foot to 1.5 feet or more, the underlying gravel beds being apparently consolidated by the excessive amount of water. In other cases the gravel was so open at first that large irrigating streams disappeared into the ground as though running into a sieve. In time, however, this open land becomes silted, and water can be used to advantage.

The ditches from the mountain streams are usually owned by individuals or by associations of ranchmen acting together and distributing the water equally or according to some agreement among themselves. Between the owners of the different ditches along the same stream, however, especially in cases where the water supply is short, there is little or no agreement. During the drought of 1889 and 1890 the necessity of efficient water supervision was appreciated more than before, and many complaints are made as to the defects of present methods, or rather lack of method, of distributing water to the ditches. All crops usually require two irrigations during the season, and at the time of the second application the water supply is, as a rule, running short, although plentiful in the preceding months; especially is this the case along Shields river, Medicine Bow and Sweetgrass creeks. In the southern part of the county, however, and especially in the southeastern part near the coal mines, where the valleys are narrow and the mountains high, it is probable that all the tillable land can be brought under irrigation by the present water supply.

SILVERBOW COUNTY is in southwestern Montana, lying across the continental divide, so that the snows falling upon the high peaks within this area furnish water to both the Columbia river and the Missouri. This is a mining county, agriculture being a comparatively unimportant industry, for the altitude is from 5,500 feet upward, and the climate is too severe for any but the hardier grains and forage crops. The city of Butte is in this county, as are several other mining towns of importance, and these furnish a ready market for agricultural products. The principal bodies of cultivated land are along the Bighole river, which forms for some distance the southwestern boundary of the county, or in the valley of the Silverbow, near Butte, in the northern end of the county. The ditches are mainly small and owned by individuals, the topography of the country being such that the irrigating ditches are quickly and cheaply made. There is ample water in the Bighole river for all the land along its banks, but in order to utilize this fully it will be necessary to construct one or more large canals. At present the water is taken out only upon the lowest land along the river and its tributaries, leaving the higher bench lands untouched, although these latter contain agricultural land as good if not better than that now utilized.

On Silverbow creek, one of the tributaries of the Deerlodge river, the water supply is not so abundant, and the irrigators state that as the timber is cut in the mountains the amount of water apparently diminishes year by year, or at least that which flows during the summer. Already several small reservoirs have been built by individuals, and others are projected. There are sites suitable for the construction of storage works, where water can be held for use upon the land along the Deerlodge valley. In some of the irrigating ditches below the mining region trouble is occasionally experienced on account of the débris or tailings from the mills, concentrators, and placer mines in the mountains. This fine material is in time of flood washed down in great quantities, and if then carried into the ditches it silts them up rapidly.

YELLOWSTONE COUNTY is a little southeast of the center of the state of Montana, lying in a southwestern prolongation of the Great Plains region, which covers the whole of eastern Montana. The surface is level or gently undulating, the general elevation being from 3,000 to a little over 4,000 feet. The county embraces that part of the plain which is south of the Musselshell river, the Yellowstone river forming its southern boundary. These rivers have carved narrow valleys through the plains, so that their bottom lands are bounded by steep bluffs 100 or more feet in height, and an observer traveling along the river courses finds them bounded by bench lands, whose nearly level surface appears to be so high above the river as to render the introduction of water upon them of doubtful practicability. The edges of these benches are in places cut by small tributaries of the Yellowstone and Musselshell or by coulees.

The principal industry is the raising of cattle and sheep, since the bench land, though dry, affords excellent grazing. Agriculture is practiced by the ranchmen, who irrigate the lower lands along the streams. The land on the benches, though apparently not so rich as that in the bottoms, would, nevertheless, be very productive, with the introduction of water. Before this can be done it will be necessary to make extensive surveys in order to determine whether it will be feasible to bring the water of the Yellowstone out upon this land. There is no question as to the supply of water in this magnificent stream or as to the possibility of bringing the water upon a portion of these high plains, but regarding the expense involved and the engineering difficulties to be encountered, as well as the acreage that can be profitably irrigated, there is much yet to be learned.

Along the Musselshell the land is rich, but the difficulty and uncertainty of obtaining water are great. The river was dry in 1890, and is always liable to be low or even to stop flowing during the latter part of the summer. On the other hand, the floods are destructive, and dams placed in the river for diverting the water have been washed out. The river is bounded by bluffs or banks so high that individual effort is rarely successful in taking out ditches, and the lands along the bottom are in general too small to repay the cost of a large canal.

There is one canal nearly 40 miles in length taking water from the Yellowstone and carrying it to Billings, thus covering a long strip of the lower land. Besides this canal, which is owned by a corporation, there are several of smaller size owned and controlled by farmers, and also a larger number of small private ditches irrigating one or two ranches. The annual cost of water from the larger canal is reported to be $2 a year per miner's inch. This quantity is commonly said to water an acre, although in fact it often covers more, and cases are reported where 40 to 50 miner's inches have raised crops successfully on 160 acres. On the other hand, where the farmer must conduct a small quantity of water in his laterals for some miles before using it, he states that it is difficult to irrigate at the rate of 1 acre per miner's inch on account of loss in transit by evaporation and seepage. Complaint is frequently made that at the rate of $2 per miner's inch the annual water dues become a burden too heavy for the ordinary farmer.

The development of irrigation is reported to have been retarded by the fact that the smaller owners can not afford to build extensive ditches, and the owners of large tracts of land, including some of the best land in the county, are holding these for speculative purposes. Most of the farmers migrated from the east, and on coming into the country either knew nothing about irrigation or believed it to be unnecessary, and it is only within a comparatively few years that the inhabitants have begun to appreciate the necessity and the possibilities of this method of agriculture. The difficulties in the way of taking ditches from the Yellowstone have prevented an extensive development of systems of small private ditches, which are so common in localities where the streams are small and easily controlled. High water ditches, that is, those receiving water in times of flood only, are, however, largely used. In a few instances the attempt has been made to raise water from the river by mechanical means, for instance, by the ancient Egyptian noria or undershot water wheel, which elevates the water by means of buckets placed on the rim of the wheel. The liability of much of this country to be visited by sudden local storms renders it necessary to locate and construct the ditches with extreme care, and to place flumes and other structures in such a manner that they will be exposed as little as possible to the torrents of rain which accompany these storms. The most notable canals in the county are briefly described below.

The Minnesota and Montana Land and Improvement Company's canal, mentioned above, takes water from the Yellowstone river at a point on the north bank about 35 miles above Billings. The total length of the canal is estimated to be 39 miles; its width, 24 feet; its ordinary capacity, approximately, 100 second-feet, and its cost, about $125,000. There is no dam across the river, the timber headgates being set in masonry, and the river banks on both sides protected by rock. This corporation sells water for the season, from May 1 to October 1, at the rate of $2 per miner's inch, measured under a 6-inch pressure. For example, the water flowing throughout the season from a box 12 inches wide, with the gate raised 1 inch from the bottom, is considered to be 12 miner's inches. It is claimed by the company that 40 inches will usually irrigate 160 acres. Farther down the river, on the north side and in succession, are the ditches known as the Italian Company's, the Mill, Clarke Fork, and the Yellowstone and Canyon Creek.

The Yellowstone and Canyon Creek canal heads about 16 miles below the canal above described and conducts the waters of the river for about 13 miles to the vicinity of Billings. The canal is 11 feet wide, carries ordinarily about 30 second-feet, and its total cost was $10,000. It is owned by about 20 stockholders, each taking an amount proportionate to the number of shares owned by him, measurement being made under a 4-inch pressure. The annual assessment for maintaining the canal is about 50 cents per acre, a portion of which can be worked out by the shareholder at the rate of $2.50 per day.

NEVADA.

Total population (average per square mile, 0.42)		**45,761**
Number of owners of farms (2.79 per cent of population)		**1,277**
Number of irrigators (91.39 per cent of farm owners, 2.55 per cent of population)		**1,167**
Area of state, land surface (109,740 square miles)	acres	**70,233,600**
Area irrigated in census year	do.	**224,403**
Area of all farms, 43.52 per cent improved	do.	**1,661,416**
Cereals raised in census year, including 54 acres in rye	do.	**15,530**
Barley, average production, 29.35 bushels per acre	do.	**8,081**
Corn, average production, 23.87 bushels per acre	do.	**274**
Oats, average production, 28.40 bushels per acre	do.	**3,490**
Wheat, average production, 22.44 bushels per acre	do.	**3,631**
Alfalfa	do.	**49,215**
Total value of all farms, including land, fences, and buildings		**$12,339,410**
Estimated total value of the farms irrigated in whole or in part		**$9,200,000**
Estimated value of all farm productions (sold, consumed, or on hand) for 1889		**$2,705,660**
Estimated value of productions, as above, from farms irrigated in whole or in part		**$2,899,000**
Average size of irrigated farms	acres	**192**
Average size of irrigated farms of 160 acres and upward	do.	**513**
Per cent of acreage of irrigated farms of 160 acres and upward to total acreage irrigated		**78.69**
Average size of irrigated farms under 160 acres	acres	**58**
Average first cost of water right per acre		**$7.58**
Average annual cost of water per acre		**$0.84**
Average first cost per acre of preparation for cultivation		**$10.57**
Average value of irrigated land, including buildings, etc., in June, 1890, per acre		**$41.00**
Average annual value of products per acre in 1889		**$12.92**

GENERAL DESCRIPTION.

One of the most notable facts concerning irrigation in Nevada is the large average size of farms, 192 acres, this being nearly three times the average for the whole western United States. This is exhibited on the diagrams in the first part of the report, which also bring out clearly the undue proportion of large irrigated holdings, namely, those containing 160 acres and upward, these forming 78.69 per cent of the total area irrigated. The small holdings, those under 160 acres in size, are in the average larger than in any of the other states and territories. This condition of affairs is due mainly to the fact that the broad, nearly level, valley lands at the foot of high mountains are easily flooded during the spring, in some places almost wholly by nature, and thus the forage crops are easily produced. Probably over 90 per cent of the land irrigated in 1889 was covered with the native grasses and other hay producing plants. The average value of products per acre was low, exceeding only New Mexico and Wyoming, and the average value of irrigated land per acre was correspondingly small.

The general condition of agriculture is somewhat peculiar, since, taking the state as a whole, tilling the soil is an adjunct to stock raising. Owing to the enormous area of the state and its small and scattered supply of water, largely from springs, the ranches or farms, excepting on the extreme western border, are at a considerable distance from each other and at still greater distances from market. Transportation is expensive, and only sufficient produce is raised to supply home or local demands. In the broad, barren valleys of the state or among the rugged hills, wherever a spring occurs, some ranchman has bought or taken up 40 acres or more, sufficient to cover the source of the water, and, owning this, he can practically control thousands or hundreds of thousands of acres of grazing lands.

The state of Nevada lies almost wholly within the Great Basin region, the only exceptions being in the northeastern corner, where the state lines include a small portion of the Snake River basin, and the southeastern corner, in the Colorado River basin on the south. The Great Basin extends on the east beyond Nevada, including nearly one-half of the territory of Utah, as well as small portions of Idaho and Wyoming, but since Nevada includes so large a part of this area a general description of the basin is essential in order to give the principal topographic features of the state. The Great Basin, as the name implies, comprises a vast area within whose rim are no streams contributing water to the ocean. All of the precipitation falling within the irregular lines bounding it must at some time be evaporated and again return to the atmosphere. In its round of life, however, the raindrop which has fallen within the basin may join other drops, becoming a rill and later forming part of a creek or large river, and then an infinitely small portion of some great lake, but from this lake it can only escape to join the ocean by taking on the form of aqueous vapor and floating away with the wind.

The Great Basin is bounded on its eastern and western sides by two great mountain masses, the Wasatch, in Utah, on the east, and the Sierra Nevada, in California, on the west. To the north and south of these ranges the boundaries of the basin are less distinctly marked, and the exact location becomes in places a little uncertain, as the line must be drawn along high plateaus or over broken country whose drainage is not well defined. These two great mountain areas, rising to heights of over 10,000 feet, by their superior altitude and consequent effect upon precipitation, give rise to many rivers, a few of which flow toward the Great Basin. Both were formed by the rising of great blocks of the earth's crust, these blocks being tilted, the uplifted edge forming the mountain crests. In each case the blocks tilt away from the Great Basin at a gentle angle and present toward it the steep, apparently vertical faces, so that the streams, which have deeply carved these great blocks, flow away down the long slope, draining comparatively large areas, while those flowing from the steeper face turn toward the Great Basin, descend with great rapidity, and have a comparatively small, though very steep, catchment area.

In the case of the streams of the eastern side of the basin in Utah the water supply is enormously increased from the fact that the rivers draining the gently sloping side of the Wasatch mountains do not flow away from the Great Basin, but turning abruptly pass through narrow, deep canyons and come out on the plains at the foot of the steep slopes. Thus it is that Utah enjoys such an unexampled water supply in spite of its otherwise unfavorable position. On the western side of the basin in Nevada, although many of the characteristics are similar to those on the opposite edge in Utah, yet this favorable circumstance is not found except to a very slight extent. The streams which rise on the far side of the Wasatch range westerly from the Great Basin continue to flow in that direction and finally enter the San Joaquin and Sacramento, so that Nevada receives only the drainage from the steeper slopes. A possible exception may be noted in the case of the Truckee river, which rises behind the Tahoe range and comes around the northern end of that range into the Great Basin. In many respects this is a counterpart of the Bear river of the northeastern side of the Great Basin, with its regulating lake and sinuous course, but in every way it is of far less size and less importance to agriculture. In short, the great streams of the eastern edge of the basin are but feebly represented on the western side.

The Great Basin as a whole rises gradually from south to north, the upper edge being at a general elevation of nearly 5,000 feet. It is higher in the center than on the eastern and western edges at the foot of the uplifted mountain blocks. Thus it is that the water collects in these depressions on each edge, forming on the west a number of small saline lakes, each fed by its own river, and on the east, with the greater water supply, a single great salt lake covering the place comparable to that of the smaller lakes on the other side. In consequence of the higher center of the basin, the greater portion of the drainage forming the Humboldt river flows from the center westerly toward the edge and there aids in the formation of the small lakes.

An almost innumerable array of smaller mountain ranges, trending north and south, fills the Great Basin and diversifies its surface by their bare and rugged peaks. Streams issue from some of these, but after a short course down the mountain sides and along a narrow valley they disappear into small saline lakes or sinks in the broader valleys between the ranges. Over hundreds or even thousands of square miles of lower mountains and desert plains there may not be a drop of water to be found during a great part of the year, and the unwary traveler is in danger of perishing from thirst. For months or even years rain does not fall on some of these vast plains, and the heat of summer renders the higher animal life almost impossible.

The climate within the interior basin has not always been as arid as at present, for within comparatively late geological time there have been fluctuations sufficient on the one hand to produce great lakes of fresh water, and on the other extreme to completely dry these, the ever-changing conditions again bringing about the abundant rainfall necessary to fill the ancient basins. The shores and beaches of these ancient lakes (*a*) form conspicuous features of the landscape of the present country, and the fine materials deposited upon their bottoms are now the level plains whose soil, when moistened, yields abundant crops.

Four rivers of notable size are formed by the drainage from the steep eastern face of the Sierra Nevadas. These are the Truckee on the north, the Carson, Walker, and Owens on the south. The first three of these flow westerly into the Great Basin and finally lose their waters in the saline lakes, the Truckee into Pyramid and Winnemucca lakes, the Carson into Carson sink, and the Walker into Walker lake. The fourth river, Owens, clings closely to the foot of the mountains and flows in a general southerly direction along the base. The Sierra Nevadas have a general northwesterly and southeasterly trend, while the state lines which bound this side of Nevada have courses which form small angles with this direction, and for this reason have a peculiar influence upon the water supply within this state.

---

[a] These ancient lakes, Bonneville on the east and Lahontan on the west, their extent and fluctuations, have been described in monographs of the United States Geological Survey.

The western boundary of Nevada coming from the north runs toward the Sierra Nevadas and crosses the eastern slope diagonally, ascending gradually toward the higher summits. When it reaches lake Tahoe it turns abruptly to a southeasterly course and descends again diagonally down the mountain slopes to the plains beyond. Within this broad angle included by the state lines where they ascend and descend the Sierra Nevadas is included the most important portion of the state agriculturally and also as regards mining industries and population. The state lines on this side by their peculiar position, in both instances diagonal to the general course of the mountains, cut the drainage basins of the Truckee, Carson, and Walker, leaving the head waters and upper valleys in California and the lower fertile plains in Nevada. The fourth stream of this series, Owens river, lying along the mountains, is by the southeasterly direction of the state line left wholly in California.

These three rivers, the Truckee, Carson, and Walker, together with the Humboldt, which flows from the center of the basin toward the western edge, comprise practically the water supply of the state. There are other small streams and many springs, but none of these are of importance save to small localities or to individuals. The development of the agricultural resources of the state, therefore, depends upon the careful conservation of the waters of these rivers, and their utilization to the greatest possible extent. This fact has long been recognized, and steps, though somewhat halting, have been taken toward the investigation of the water supply and the best means of increasing the utilization of it. In all projects, however, Nevada as a state is hampered by the fact that her principal streams derive the greater part of their water from catchment areas lying within the state of California.

STORAGE RESERVOIRS.

There are many excellent localities for the construction of storage reservoirs upon the head waters of the Carson and Truckee, by which the excess waters of the early spring floods could be held for use later in the season. Surveys have been made of a number of the more important of these, and they have been reserved, at least such portions of them as belong to the United States, for reservoir purposes. The reservoir which has attracted the greatest amount of popular attention is lake Tahoe, and it has been urged that by holding its waters back by means of a suitable dam enormous quantities can be retained for the irrigation of thousands of acres. There is however, a question of water supply of the lake involved in this project which is seldom taken into account. The drainage area tributary to the lake of 506 square miles is, in proportion to the open water surface, which amounts to 192 square miles, exceedingly small, and it is doubtful whether in every year the lake can be raised to a height sufficient to furnish water to the amount anticipated. In this respect lake Tahoe is comparable to Bear lake and Utah lake on the eastern side of the Great Basin, namely, in being too large for economical water storage. The expense, however, of holding water within the lake would be very small, since the outlet can be readily controlled. One obstacle to the use of this lake as a storage reservoir for the dry lands of Nevada is that the lake is principally in California, as is also the natural outlet and a large part of the course of the Truckee river, which flows from it. The outlet is now under the charge of lumbermen, who use the water from the lake at certain seasons of the year to carry logs to the sawmills below.

In addition to the reservoir sites occupied in part by lakes, and to which public attention has been especially drawn, there are a number of localities scattered through the mountains at the head waters of the streams, many of which are suitable for holding water. These are mainly valleys, in some cases formerly occupied by glaciers and later by small lakes which in course of time have cut an outlet through the lower rims. A comparatively small expenditure of labor and capital will close the outlets, and by this means bodies of water of considerable size can be held. As previously mentioned these localities are mainly in California, while the lands to be benefited are far down the stream upon the deserts of Nevada, and there is uncertainty as to the requisite co-operation on the part of California in forwarding such enterprises. Another drawback is that these localities are in general owned and occupied as dairy farms, and a large price is put upon them whenever the matter of water storage is discussed.

FLUCTUATIONS OF WATER SUPPLY.

There is usually ample water for these storage reservoirs, which can be filled in April, May, or June during the height of the floods or during the winter months. The distribution of water in the streams throughout the year is perhaps best shown by the table on the following page, which gives the percentage of discharge month by month. With this is placed the percentage of rainfall for immediate comparison. The actual quantities of water in many of the important streams are given in tabular form under the descriptions of the counties on the following pages.

MONTHLY PERCENTAGE OF RIVER FLOW AND RAINFALL.

MONTHS.	Average run-off. (Per cent.)	Average rainfall. (Per cent.)
January	2.7	15.8
February	2.8	13.0
March	4.6	10.2
April	10.2	9.6
May	24.7	9.0
June	22.8	5.8
July	15.3	2.5
August	5.3	1.8
September	3.3	2.5
October	3.0	6.8
November	2.6	9.0
December	2.7	14.0

The above percentages of run-off relate strictly to the discharge of the Carson river for 1890, but it may be assumed that the Truckee and Walker follow about this general order. It is probable that the distribution of water in the Humboldt varies somewhat from this, a greater proportion flowing in March and less in June, the flow during fall and winter also being somewhat smaller. From an inspection of the table it appears that nearly one-half of the total amount of the water carried by the river comes in May and June, the amount falling off rapidly, so that by the end of July the rivers are below the average for the year. The distribution of the rain throughout the year has been taken from the records of the signal service obtained at 13 stations in the state where observations have been carried on for a period of at least 18 years. The average annual rainfall recorded at all of these stations was a little over 6.10 inches. Taking the months from November to March, inclusive, 62.00 per cent of the total rainfall for the year fell, this amounting to 3.78 inches. In the 7 months from April to October the average precipitation for all these stations was only 2.32 inches. It should be noted, however, that the localities where these measurements of precipitation were made are mainly in the Great Basin, away from the mountains, and at altitudes of from 4,000 to 6,000 feet.

It is evident from a consideration of these figures that farming without irrigation is practically impossible, except possibly on low grounds wet by seepage. Not only is the amount of rain exceedingly small but the distribution throughout the year is not favorable to the needs of agriculture, since such a large proportion falls during the winter. The average rainfall, 6.10 inches, above noted, does not by any means represent the rainfall in the Sierra Nevadas. As examples of precipitation at localities among the mountains may be given Boca, Cal., at an altitude of over 5,550 feet, with a mean annual rainfall for over 18 years of 15 inches; also Truckee, Cal., at an altitude of 5,820 feet, and rainfall of 27 inches. Still higher in the mountains, at Summit, Cal., where the altitude is 6,765 feet, the mean annual rainfall for 17 years was over 42 inches. It is from this abundant precipitation, mainly in the form of snow on the high mountains, that the rivers receive their supply. At rare intervals heavy storms may occur out in the basin, but these are of comparatively little value to agriculture, and in fact may be injurious. The rains falling upon the perfectly level lands in the center of some of the valleys sometimes convert them into broad lakes, the water standing to a depth of a few inches for several hours or days until evaporated.

In the employment of waters in irrigation it has been found here, as in other localities, that the irrigation of the higher land on the edge of a valley helps to water the lower ground, and that less water is required on the latter, and in some cases forage crops can be successfully raised by seepage alone from higher land. When water is first applied to the soil it often sinks in so rapidly that even with a large stream it seems impossible to saturate even an acre. Gradually, however, the water level is raised in the surrounding lands, and in the course of months or years the ground water of the vicinity has come so near the surface that a comparatively small amount of water suffices for a season's irrigation. The rise of the ground water is attested by the fact that wells previously sunk in dry earth to depths of 60 to 100 feet without reaching water are in some cases filled to within a few feet of the surface.

WELLS.

The waters from wells and springs have an exceptional value in Nevada on account of the general scarcity of surface waters. Taking the state as a whole, there are a large number of springs the waters of which in many cases are warm or hot and often too heavily charged with mineral matter to be useful for agriculture. There are a few shallow flowing wells in the state, notably in the vicinity of Carson. A number of deep holes have been drilled in different parts of the state, but without success so far as flowing wells are concerned. It is reported that a well was sunk by the railroad company at White Plains, Churchill county, west of the Humboldt and Carson sinks, to a depth of 2,345 feet, but without reaching water. Another well at Lovelocks, Humboldt county, north of Humboldt sink, was put down to a depth of 1,000 feet, but without success.

On the lower lands in Ormsby county are a number of small flowing wells from 100 to 150 feet in depth, delivering a quantity of water ranging from 2 to 25 gallons per minute each. Other small flowing wells have been found in Carson valley in Douglas county, in Washoe valley in Washoe county, on the low lands of Churchill county, near Battle mountain and Austin in Lander county, and also in Eureka and White Pine counties. In general it may be said that these wells vary in depth from 50 to 300 feet, are from 2 to 6 inches in diameter, and cost from $1 to $6 per foot according to depth and the success of the driller. The amount of water delivered is very small, almost insignificant in comparison to that carried by a small irrigating ditch, but is valuable for watering stock and for domestic purposes.

These wells are in many respects similar to those of Utah along the edge of Utah lake and Great Salt lake. It appears probable that in all of these valleys in which irrigation has been carried on for a number of years the waters have permeated the unconsolidated deposits of sand and gravel. These being interstratified with beds of clay and dipping slightly toward the center of the basin give rise to conditions favorable for small flowing wells in the lower portions of each valley. When a pipe is driven down through these alternating beds and penetrating the clay layers enters the gravel or sand, the water tends to rise to the surface and overflow if the top of the pipe is below the general level of the valley.

The probabilities of obtaining large artesian wells in the valleys of Nevada do not seem from present knowledge at all favorable, both because the deep wells drilled within the past few years have been in general dry, and because the large number and wide distribution of springs indicate a dislocation of strata unfavorable to the production of artesian wells. Exploration in this regard is being carried on occasionally, and it is possible that flowing waters of considerable local value, especially for supply of cattle, may be obtained.

IRRIGATING DITCHES.

The irrigating ditches of Nevada for convenience have been arranged in two groups, the first consisting of those having an average width of less than 5 feet and the second those of a width of 5 feet and over. The average cost per running mile of the smaller ditches has been found to be approximately $200 and of the larger $1,150 per mile, including in this the cost of headworks, flumes, and other structures. The average width of these larger ditches is about 8 feet, and there are comparatively few averaging over 10 feet in width, so few in fact that a separate class of this dimension has not been made as in the case of other states.

The average area irrigated by each ditch is 530 acres, excluding from this computation a number of larger ditches reported to irrigate tracts of unusually great size. For comparison with this, it should be noted that in Idaho the ditches irrigate on an average 385 acres and in Montana 225 acres, excluding in these cases a few of the large canals. This large acreage to each irrigating ditch is due not to better construction but rather to the fact that throughout a great part of the state irrigation is still in the first steps of development, not having advanced beyond the simple and wasteful methods of flooding the ground. Not only is a great portion of the water wasted but the results obtained are often of less value than would have been the case in the employment of better methods of irrigation, for by the use of too great an amount of water some of the most valuable species of native grasses are drowned out, coarse swamp grasses taking their places. The employment of too much water by one man not only diminishes the supply for other persons, but may injure the property of the user.

In the construction of these irrigating ditches little, if any, outside capital has been employed, but they have been dug by the irrigators, acting individually or in co-operation. The ownership is almost wholly within the hands of the farmers, and the administration of the water, if the general lack of system can be called such, is wholly within the control of the men who are directly benefited. Owing to the multiplicity of ditches deriving water from the same stream and the many separate interests involved, there constantly arise conflicts between irrigators as to the distribution of water, especially during the seasons when the supply is scanty.

CONDITION OF IRRIGATION IN EACH COUNTY.

NUMBER OF IRRIGATORS, AREA IRRIGATED, FARMS, AND CROPS IN EACH COUNTY IN NEVADA IN 1889.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.	OWNERS OF FARMS. (a)		IRRIGATORS.		Area of counties in acres.	FARM AREA.		Cereals. (Acres.)	Alfalfa. (Acres.)	AREA IRRIGATED.			Average value of products per acre.
				Total number.	Per cent of population.	Per cent of farm owners.	Per cent of population.		Acres.	Per cent improved.			Per cent of area of county.	Per cent of total farm area.	Per cent of land owned by irrigators.	
Total	1,167	224,403	192	1,277	2.79	91.39	2.55	70,233,600	1,661,416	43.52	15,530	49,215	0.32	13.51	14.18	$12.92
Churchill	43	9,688	225	43	6.12	100.00	6.12	3,105,280	52,780	81.06	449	3,643	0.31	18.36	18.36	10.33
Douglas	26	4,250	163	38	2.45	68.42	1.68	570,880	22,502	61.42	1,429	822	0.74	18.89	22.78	9.68
Elko	250	56,305	225	262	5.47	95.42	5.21	11,297,280	538 527	48.55	5,799	3,911	0.50	10.46	10.78	8.49
Esmeralda	29	4,527	156	30	1.40	96.67	1.35	5,465,600	19,060	56.35	481	1,895	0.08	23.75	23.95	12.34
Eureka	38	6,344	167	41	1.25	92.68	1.16	2,656,000	143,390	8.89	2	2,633	0.24	4.42	4.45	19.10
Humboldt	116	56,680	489	147	4.28	78.91	3.38	10,611,200	418,815	45.01	8	5,938	0.53	13.53	13.85	14.44
Lander	52	7,857	151	59	2.60	88.14	2.29	3,389,440	71,129	24.22	913	623	0.23	11.05	13.52	16.45
Lincoln	95	4,400	46	98	3.97	96.94	3.85	11,315,200	18,805	54.78	971	410	0.04	23.40	24.48	13.94
Lyon	87	17,777	204	87	4.38	100.00	4.38	808,960	49,445	54.91	1,142	10,816	2.20	35.95	35.95	13.03
Nye	82	8,366	102	98	7.60	83.67	6.36	10,821,120	36,425	49.93	771	706	0.08	22.97	23.99	13.81
Ormsby	26	1,497	58	29	0.59	89.66	0.53	92,160	8,002	62.20	301	1,175	1.62	18.71	20.25	31.55
Storey	1	120	120	1	0.01	100.00	0.01	172,800	320	37.50	15	105	0.07	37.50	37.50	....
Washoe	221	28,631	130	235	3.65	94.04	3.43	3,596,800	153,591	32.15	1,575	13,788	0.80	18.64	20.45	18.85
White Pine	101	17,961	178	109	6.33	92.66	5.87	6,330,880	128,625	51.06	1,674	2,750	0.28	13.96	16.07	12.33

a Includes owned and hired farms, assuming one farmer to each.

CHURCHILL COUNTY is in western Nevada, east of the row of small counties along the foot of the Sierra Nevadas. It contains on the extreme west a portion of Winnemucca lake, into which the Truckee flows, and on the north a part of Humboldt lake at the lower end of the Humboldt river. The most important bodies of water are Carson lake, near the southwesterly side of the county, and Carson sink, to the north of this, occupying evidently the lowest portion of this part of the Great Basin, since the drainage of the Truckee, Humboldt, and Carson finds the last resting place and ultimately disappears by evaporation. Carson river, entering the county from the west, flows in a general easterly direction, meanders through the nearly level bottom lands, and dividing into several channels discharges into Carson lake to the south or into the sink toward the north. In the broad valley in the vicinity of these lakes there are probably over 100,000 acres of rich land, the greater portion of which is lying idle for lack of water. The general altitude of this low land is under 4,200 feet and the climate is favorable for the production of large crops. The lands at present tilled form an insignificant part of that which could be brought under cultivation if water could be secured. By the construction of reservoirs at the well known sites along the Carson above this valley, ample water could be obtained for the irrigation of a portion at least of this desert area.

The present agricultural lands are along the Carson river and its various channels. Water is taken from the river and its sloughs by over 50 ditches, each leading to one or more ranches. The lower lands near the lakes have mainly an adobe soil, which, though fertile, is not as rich as that of the desert lands farther back from the river, but can be brought under cultivation at small expense. The water for irrigation is allowed to run on wild grass until the quantity is equal to that which would cover the surface to a depth of from 3 to 4 inches, the stream flowing steadily for 8 or 10 days, after which the water is turned off for a week or more, and then allowed to run upon the field again. Large areas of grass are thus brought under irrigation at small expense and with little labor, and great quantities of water are used at times when it is plentiful.

There are thousands of acres of good land in this county lying back from Carson river at an elevation slightly too great to admit of bringing water upon them except by the construction of long and expensive canals. In one case at least water is raised by means of a pump driven by an engine. This is said to deliver water at the rate of 100 miner's inches, irrigating 1 acre in 2 hours. The cost of the pump and engine is reported to have been $1,200. The fuel used is sage brush.

DOUGLAS COUNTY is the most southerly of those on the west side of Nevada and occupies the broad angle made by the change in direction of the line between this state and California. It extends easterly from Tahoe lake nearly to the Walker river, including in its southern extremity a portion of the West Walker. The east and west forks of the Carson flow from California northerly into this county and unite in the Carson valley, whose bottom lands have an altitude of from 4,700 to 5,000 feet. The agricultural land of the county is within this valley, mainly on the western side, water being taken from the east and west forks, and also from the small creeks which come down from the Tahoe mountains. On the east side of the Carson valley are broad deserts, whose fertile lands could be rendered highly productive by the use of waters obtained by storing the floods of Carson river. These lands are owned largely by a few individuals, some of whom have discussed the feasibility of attempting the construction of reservoirs. Examinations conducted by the United States Geological Survey and by private enterprise have furnished data by which the cost of these improvements can be computed, and a large amount of information is available as to water supply and storage capacity, sufficient to show the feasibility of such schemes. The extension of agriculture in this county by use of stored waters rests upon the questions of water control and of securing sufficient capital to construct the systems. The information at hand carries the matter beyond the preliminary stages, and is sufficient to justify organization for definite ends. In the lower part of Carson valley is a locality suitable in many ways for the construction of a reservoir to hold waters for use upon the lands below Dayton in Storey county. In short, there is no lack of localities favorable for water conservation, the obstacles being of a financial or legal character rather than those offered by nature.

The quantity of water in the East and West Carson rivers has been measured at points (*a*) above the valley, the gauging station on the East Carson being at the Rodenbah ranch, about 14 miles from Genoa and 22 miles from Carson, and that on the west fork of the river being about one-half mile above the town of Woodford, Alpine county, California, which is 20 miles from Genoa and 32 miles from Carson.

The main Carson was measured on June 10, 1889, below the junction of the east and west forks. The discharge at that time was only 527 second-feet, a great part of the water being diverted by irrigation ditches at points above. In 1890 a station was established at the lower end of the Carson valley, near Empire, thus giving the discharge as shown above available for the valleys farther down below Dayton, in Lyon county.

---

[a] The results are given in the following tables:

DISCHARGE OF EAST CARSON RIVER AT RODENBAH, NEVADA.

(Drainage area, 414 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1890.						
April 7 to 30	1,565	752	1,026	61,047	2.76	2.48
May 4 to 31	4,260	1,315	2,654	163,221	7.38	6.41
June	3,900	1,745	2,430	144,585	6.55	5.87
July	2,780	750	1,789	110,024	4.98	4.32
August	875	437	597	36,715	1.66	1.44
September	437	400	415	24,692	1.12	1.00
October	390	385	386	23,740	1.07	0.93
November	385	380	384	22,848	1.04	0.93
December	400	375	379	23,308	1.06	0.92
1891.						
January	395	385	388	23,862	1.08	0.94
February	715	377	402	22,311	1.01	0.97
March	1,650	390	783	48,154	2.18	1.89
April	590	410	452	26,894	1.22	1.09
May	1,884	1,010	1,445	88,867	4.02	3.49
June	1,884	565	1,328	79,016	3.58	3.12
July	1,190	445	618	38,007	1.72	1.50
August	447	390	408	25,093	1.14	0.99
September	400	385	388	23,086	1.04	0.93
October	385	385	385	23,677	1.08	0.93
November	385	385	385	22,907	1.05	0.93
December	480	385	438	26,937	1.19	1.06
Per annum	1,884	377	619	448,810	20.31	1.50
1892.						
January	405	375	390	23,985	1.08	0.94
February	400	290	388	22,310	1.00	0.94
March	445	400	422	25,953	1.17	1.02
April	535	400	478	28,441	1.29	1.15
May	2,590	480	1,226	75,400	3.41	2.96
June	1,790	715	1,158	68,782	3.11	2.81
July	715	420	506	31,119	1.40	1.22
August	420	410	413	25,390	1.15	1.00
September	420	410	414	24,633	1.12	1.00
October	420	410	416	25,584	1.16	1.01
November	535	400	414	24,633	1.12	1.00
December	5,540	400	1,097	67,465	3.06	2.65
Per annum	5,540	290	610	443,704	20.07	1.47

DISCHARGE OF WEST CARSON RIVER AT WOODFORD, CALIFORNIA.

(Drainage area, 70 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1890.						
April 9 to 30	448	145	284	16,898	4.56	4.06
May	924	318	657	40,405	10.83	9.40
June	1,284	448	614	36,533	9.79	8.77
July	606	252	380	23,370	6.27	5.43
August	240	90	135	8,302	2.23	1.93
September	86	70	75	4,462	1.09	1.07
October	78	54	67	4,120	1.10	0.96
November	58	46	49	2,915	0.78	0.70
December	58	42	53	3,259	0.87	0.76
1891.						
January	62	46	52	3,198	0.86	0.74
February	58	42	48	2,664	0.71	0.69
March	68	50	61	3,758	1.01	0.87
April	384	62	127	7,556	2.02	1.82
May	740	300	534	32,820	8.79	7.62
June	456	260	338	20,111	5.38	4.83
July	280	82	130	7,995	2.14	1.86
August	78	50	65	3,997	1.07	0.93
September	50	34	41	2,439	0.65	0.60
October	54	42	48	2,952	0.80	0.69
November	50	38	43	2,558	0.69	0.61
December	54	42	47	2,890	0.77	0.67
Per annum	740	34	128	92,938	24.89	1.83
1892.						
January	46	42	45	2,767	0.74	0.64
February	54	38	46	2,645	0.69	0.66
March	74	54	65	3,997	1.07	0.93

DISCHARGE OF MAIN CARSON RIVER AND FLUME, NEAR EMPIRE, NEVADA.

(Drainage area, 894 square miles.)

1890.						
April 16 to 30	2,307	1,337	1,565	93,117	1.95	1.75
May	6,278	1,751	3,475	213,712	4.48	3.89
June	4,276	2,311	3,143	187,008	3.92	3.52
July	3,115	1,491	2,159	132,550	2.79	2.41
August	1,421	215	756	46,494	0.98	0.85
September	215	131	144	8,568	0.18	0.16

Elko county is in the northeastern corner of Nevada, adjoining Idaho on the north and Utah on the east. The greater part of the county is on the head waters of the Humboldt river, containing the catchment areas of the north, east, and south forks, which unite to form that stream. On the extreme north it also contains the head waters of Salmon creek and Bruneau river, which flow north into the Snake, and the east and south forks of the Owyhee flowing northwesterly into Idaho and Oregon. The northern part of the county consists of a great plateau 7,000 feet and upward in elevation, little known except perhaps to prospectors and to a few cattle men. In the southern part of the county, however, the topography is similar to that of the rest of the state, namely, high mountain ranges trending in a north and south direction with long, narrow valleys between them. From some of these mountains, as, for example, the Ruby and Humboldt ranges, a large amount of water flows in the various streams during the spring and early summer, thus rendering possible the cultivation of land along the base of the mountains. The agricultural land of the county is scattered, being in small patches where a stream comes out from the canyons upon nearly level land. Cattle raising is the chief industry, and irrigation is carried on mainly for the purpose of obtaining hay for winter feed, and to a less extent for pasturage for the stock, for which as a rule the larger part of the feed is found in the higher valleys among the mountains. A comparatively small amount of grain is also raised, as well as some vegetables for home use. The acreage in small grains has diminished during the past few years, owing to the lack of markets and to the high freight rates. As a rule the lands formerly used for grain have been planted to alfalfa or other forage crops and are being converted into hay lands.

The crop area as a whole has diminished owing to the droughts of 1888 and succeeding years and the unusually severe winter of 1889–1890, during which a great part of the cattle perished, in a few cases as high as 90 per cent. The expense of transportation is so great that with the decline of mining industries farming has hardly held its ground, and considerable hardship has been experienced by the greatly scattered agricultural population. The water supply as a rule is in ordinary seasons ample for present needs, except perhaps during the latter part of the year. The ranches being some distance apart and in most cases each upon its own mountain stream or group of springs, there is little complaint of interference of water rights.

In many localities the storage of spring water is necessary to insure a constant water supply and an increase of cultivated area. There are a number of excellent reservoir sites in the county, especially on the south fork of the Humboldt, where there is an abundance of water from the Ruby mountains; also on Bishop creek and on the head waters of Mary river and north fork of Humboldt, as well as on Susie and Maggie creeks. There is apparently ample water to fill reservoirs each year, and if built they will be of value not only to this county but also to lands in Eureka, Lander, and Humboldt counties along the course of the river. In one instance at least storage reservoirs have been constructed, and they are reported to be a financial success to the owners.

There are a great number of valleys in this county, on the edge of each of which are ranches utilizing nearly all of the available water. The principal groups of ranches are those in the vicinity of Tuscarora, on the head waters of the south fork of the Owyhee, and of the streams flowing southerly into the Humboldt; also along the east fork of the Humboldt from Wells westerly, along the western side of Ruby and Clover valleys, and on the south fork of the Humboldt. The methods of irrigation practiced in all these localities are of the simplest and least expensive kind. The streams diminish greatly in size or become dry in July, and therefore as much water as possible must be used early in the season. The irrigating ditches are plowed out to a size sufficient to bring water out of the stream bed, in which it is prevented from flowing by rough dams. The higher "sage brush" lands in general are planted to alfalfa, and the lower to grasses, timothy and redtop doing well on the bottom lands. By the irrigation of the alfalfa on the higher, more porous soil, the lower grounds usually become thoroughly wet and almost swampy in places. It is thus a matter of difficulty to make careful comparisons of cost and values of this kind of irrigation with those where the methods are more highly developed, for here, where thousands of acres are wet by simple diversion of a stream upon the higher edge of nearly level land, it becomes almost impossible to obtain with any exactness the crop area actually irrigated, since the distance the water penetrates and consequent area covered vary greatly with the season and character of the soil.

Esmeralda county is in western Nevada lying along the state line adjacent to California, and having a general northwesterly and southeasterly direction. The northern half of the county is traversed by a narrow gauge railroad connecting with the Central Pacific at Reno and running south to Owens lake in Inyo county, California. The East Walker river rises in the Sierra Nevadas north of Mono lake in California, and flowing easterly and northerly, crosses the state line into Esmeralda county, and continues northerly into Lyon county, where it joins the West Walker. The main stream flows first north, then east, then southeast, returning into Esmeralda county, and emptying into Walker lake, whose waters escape only by evaporation. The portion of the East Walker which is included within the county lines and the streams immediately tributary to it furnish the greater part of the water supply available for agriculture. A number of small streams, however, issue from the mountains to the east of the East Walker river and furnish a small supply of water for the broad valley to the south of Walker lake.

The situation of this county in the valleys below the main range of the Sierra Nevadas adds to the difficulties of developing agriculture. The best reservoir sites are in another state, being on the head waters of the East

Walker in Mono county, California. There the waste water of the spring could be held to advantage for use upon the fertile valleys of Esmeralda and Lyon counties were it not for complications arising from state lines.

The unregulated water supply is so uncertain that the development of the resources without water storage is impossible. In 1889 the Walker river was dry in Mason valley, owing partially perhaps to diversions of water in Mono county, California. Several of the smaller tributaries of the East Walker, which rise within the borders of the county, can be wholly controlled, and small reservoirs can be constructed upon them, thus obviating any interstate complications, and there are probably other sites suitable for water storage on the small streams entering the larger valleys, so that many thousand acres can be redeemed even if the better sites in California are not utilized.

As a rule, owing to its scarcity water is used a little more economically in this county than in localities farther north. Irrigation is usually by means of small furrows about 30 inches apart, or by the check system, small ridges of earth being thrown up to hold the water to a given depth over each part of the field. Along the streams there are a few small meadows where clover, wire grass, and the native redtop receive sufficient moisture to grow, but these are of little importance in comparison with the irrigated forage crop. A great part of the lower ground is impregnated with various mineral salts, often requiring one to three years' irrigation before these are washed out. In some of the valleys the concentration of these salts, borax especially, is so great that they become a source of revenue.

EUREKA COUNTY is a little east of the center of Nevada, and comprises a narrow strip extending in a north and south direction, its northern end being crossed by the Humboldt river, along which are a number of ranches. It lies south and west of Elko county, to which it is similar in many respects, a description of the irrigation in that county applying to the condition of affairs in this. It has an advantage over some of the other counties of the state in being traversed by a north and south line of railway, which connects with the Central Pacific at Palisade and extends southerly to Eureka and to the mines at Ruby Hill. This railroad was built for the purpose of transporting mineral products and lumber, and is of less importance to agriculture, on account of the high rates for freight. It carries a comparatively large tonnage of hides and wool. Away from the vicinity of the Humboldt and of Trout and Pine creeks the water supply of the county is very scanty, and the prospects are not encouraging as to future development of agriculture by irrigation.

HUMBOLDT COUNTY is in northwestern Nevada adjoining Oregon, and separated from California only by the comparatively narrow Washoe county. It contains the lower course of the Humboldt river and the greater part of the sink where the waters of this river disappear by evaporation. The surface of the county consists of alternations of short mountain ranges rising to heights of 7,000 or 8,000 feet above sea level, some of the peaks reaching altitudes of over 9,000 feet. Lying between these ranges are nearly level valleys, the soil of which has been deposited from ancient lakes, or has been made by the action of wind and rain in bringing particles from the mountain masses. Among the mountains are many springs, which sometimes unite to form small streams. These brooks and creeks are swollen during the spring by the melting snow, and their waters flow out upon the desert valley land, but during many months of the year their beds and channels become dry, except high among the canyons.

The Humboldt is a river of entirely different character from the streams issuing from the Sierra Nevadas, so that direct comparisons can not be made. In many respects it is more like the Owyhee and the Malheur of eastern Oregon, which rise directly north of the Humboldt and flow in a general northerly and easterly direction into the Snake. Series of gaugings have not been made on the Humboldt, but two measurements are given by Russell in his monograph on lake Lahontan. These measurements were made below the mouth of the Little Humboldt, where the total drainage area was 10,600 square miles, that of the Little Humboldt alone being 1,650 square miles. The discharge on September 10, 1881, when the river was at the lowest stage of the year, was 48 second-feet, and on July 17, 1882, it was 750 second-feet. At this latter time the height of the river had fallen 3 feet from the maximum of the year and was declining rapidly, the discharge two weeks later being nearly one-half the amount given. A still later measurement of the river during a June flood showed a discharge of over 2,000 second feet. Humboldt lake, into which this river discharges, is reported to have been dry in 1879, but following this time of drought came high water which raised the lake until in 1882 it stood at a higher level than immediately before the drought. The amount of water in this lake, as in the case of all the other sinks of rivers, gives evidence as to the quantity which might be held by storage at points higher on the stream, and without further discussion it is evident that great areas can be brought under cultivation by thus storing the water and preventing the waste by evaporation as the water finds its way down the long sandy channel of the stream.

The principal streams of the county, besides the Humboldt, are King, Quinn, and Little Humboldt rivers. Quinn river rises in the valley between Disaster peak on the west and the Santa Rosa mountains on the east. It flows southerly through this valley, its channel turning westerly around the northern end of Jackson mountains to Blackrock desert on the western side of the county. During the time of melting snow a considerable amount of water flows down the channel to the desert, whose surface is so level that the water spreads out into a large lake of many miles in extent, but having a depth of only a few inches. This lake dries again in a few weeks, leaving the desert perfectly arid for the rest of the year.

King river rises in the valley to the west of the head waters of Quinn river, and flows southerly, its channel joining that of Quinn river above Blackrock desert. In floodtime, therefore, it contributes its share toward converting the desert into a lake. The Little Humboldt receives its water from the east side of the Santa Rosa mountains, south of the head waters of the Little Owyhee river, a portion of the Columbia drainage. The waters tributary to this stream seldom reach the main channel, although at times of unusual flood the Little Humboldt flows south to the Humboldt, joining it above Winnemucca. It may be said of the streams of this county that for the brief flood time of spring there is an excess of water which spreads out and fills the low valleys, while for the rest of the year not a drop of water is to be had except from an occasional spring in the mountains.

The Humboldt river itself is the only exception to this rule as to complete drought during the greater part of the year, for water has flowed continuously in its channel down to the Humboldt sink for 30 years at least, except in 1889. During this year of unusual scarcity the water was entirely used by the ranchmen along the upper courses of the river, little, if any, reaching the lower meadows. For this reason thousands of acres of hay land which had been cropped continuously for some years did not yield sufficient to repay the trouble of cutting. This condition may be regarded as unusual, but as it has occurred once the probabilities are that it will happen again, especially as the tendencies are toward greater and greater diversion of the water of the tributaries of the Humboldt.

The irrigators along the lower course of the river are anxious to secure some system of storing the excess water of the spring, for they fear that they will be deprived of their supply more frequently in future. The irrigators having ranches from Winnemucca down to the Big Meadows, where the soil is especially fertile, as a general thing, have first right to the water, but in spite of this fact they are not able to secure the amount to which they are probably entitled by prior appropriation. Lawsuits have been tried in the hope of compelling irrigators higher on the stream to turn down the water, but this, as is generally the case, has been of little real benefit. It seems practically impossible, in spite of laws or regulations, to compel one man to deliberately destroy his own property by turning away water in order to benefit individuals 100 miles away.

The principal body of irrigated land is along the Humboldt river and down toward the sink. Much of this rich land is very low, and it is hardly necessary to dig ditches to bring water upon it, for the annual rise of the river produces a natural irrigation, or in many cases water is raised and diverted by a dam across the river, causing large areas to be overflowed. Later in the season much of this ground is wet from beneath by seepage through the subsoil. Thus it is exceedingly difficult, if not impossible, to distinguish between the crops raised by irrigation, as the term is commonly employed, from those raised by the perfectly natural methods of overflow and seepage. The greater part of the land of the county is irrigated for hay, the acreage of cereals and vegetables being almost insignificant. The size of the ranches is very great, each containing several hundreds or even thousands of acres. On the irrigated land the heaviest of the hay only is cut and the cattle are turned in to graze upon what is left.

In Paradise valley on the Little Humboldt are large ranches irrigating hay crops principally, and there are at least 20 ditches taking water from Martin creek, the principal tributary of the Little Humboldt. This stream rises among peaks of the Santa Rosa mountains, whose heights are upward of 8,000 feet, and therefore it receives a comparatively large amount of water. On the head waters of Quinn river there is some irrigation for the purpose of raising feed for cattle and for small patches of grain and gardens. All the natural supply of this river has long since been appropriated. Besides these localities are several places, as in Pleasant valley south of Winnemucca, where irrigation is carried on near the foot of the mountains.

LANDER COUNTY is nearly in the center of Nevada, lying southeast of Humboldt county. Like Eureka county it extends in a general north and south direction and is traversed by a railroad running from Battle mountain on the Central Pacific to Austin, the headquarters for the mining and stock raising trade of that part of the state. Humboldt river crosses the northern end of the county and Reese river flows from the south, in time of flood contributing to the Humboldt. During the latter part of the summer and in the fall the river channel is dry at some distance above the junction of these two streams. There are thousands of acres of fertile land along Reese river, for which there is no apparent supply of water. From the head waters downward the stream in times of low water disappears in the sandy channel, water reappearing at various points where springs rise in the bed or sides. Cattle ranches are scattered throughout the county wherever there is water to be found for the stock and all of the streams are utilized in most seasons to their full extent for flooding the hay crops. In Smith Creek valley and also in Reese valley near Battle mountain are flowing wells of a depth of from 150 to 750 feet. The water from these wells is used for stock and the excess is allowed to flow out upon the ground, watering one or two acres of grass or occasionally small gardens. Along the Humboldt river are places, as in Eureka and Humboldt counties, where by the spring overflow of the river crops of hay are raised.

LINCOLN COUNTY is in the southeastern corner of Nevada, adjoining Utah, Arizona, and California. It extends from the Colorado river northerly half the length of the state, embracing on the south a great portion of the lowest part of the state, areas of considerable size near the Colorado river being below an altitude of 2,000 feet. The annual rainfall is very small, being from 8 inches down to less than 1 inch. The average for over 5 years at Pioche, where the altitude is about 6,200 feet, has been 6.5 inches. The southern and lower portions of the county are thus exceptionally dry, and the climate is semitropical in character, so that wherever water can be obtained the more valuable fruits can be raised, as well as cotton and sugar cane.

The principal agricultural settlements are along the Pahranagat valley; also along Muddy river, which flows into the Virgin, and on the Virgin river. The water supply of the Pahranagat valley is derived from a number of large springs which rise at intervals along the mountains. The most northerly of these is known as Hiko spring. About 5 miles south of this are Crystal springs, and farther south is Ash spring. The farming land lies in a narrow belt about 30 miles long and less than a mile in width. The springs deliver a nearly constant supply of warm water, which flows down the valley and forms a lake at the southern end. The lowest land was formerly a marsh, and requires draining followed by irrigation. In fact, the farmers on the lowest ground complain that for a large part of the year their land is under water, while the rest of the year they may suffer from drought. Above the low bottom land is a broad bench, furnishing excellent grazing for cattle during certain seasons of the year. If the water of the springs could be conducted out upon a portion of this bench by means of well built canals a larger area of better land could be brought under cultivation. With the present lack of markets and the impossibility of transporting the produce, it is doubtful whether such projects would repay their cost. At present the principal occupation is stock raising, and only sufficient of the small grains, vegetables, and fruits is produced to supply local consumption.

Along Muddy river, in the vicinity of Moapa and Overton, are a number of ranches, on each of which a small amount of grain is raised. On Virgin river the farms in the vicinity of Bunkerville are in many ways similar to those in Washington county, Utah. The bed of the river is constantly changing, rendering irrigation difficult and expensive, and the occasional heavy summer storms not only destroy crops but even wash away portions of the agricultural land. The climate is so favorable that the most valuable crops can be raised with success, and 5 cuttings of alfalfa can often be obtained. In this hot climate water must be used with great care on account of the presence of alkaline salts in the soil. In many cases the water can not be applied directly to the surface, for on evaporating it leaves a thin crust through which the young plant can not penetrate. The water is applied by means of small ditches or furrows at intervals of 30 or 40 feet, covering the field, the water saturating horizontally the intervening space but not wetting the surface.

LYON COUNTY is in western Nevada, a portion of it lying between Douglas and Esmeralda counties, the greater part, however, being to the east of the cities of Carson and Virginia. It is in general form somewhat the shape of a four-pointed star, one narrow projection running northward to the Central Pacific railroad, another westward up the Carson river to the quartz mills, the third eastward along a portion of the lower Walker river and out upon the desert south of Carson lake, and the fourth projecting southwesterly up the main Walker and the West Walker for a portion of its course, and then leaving the river continuing in a narrow strip to the state line of California. It thus includes Smith valley on the lower part of the West Walker river, Mason valley on the main Walker, and Churchill valley on the Carson.

The principal agricultural areas are in Mason valley, where the East and West Walker rivers unite. Here the altitude is a little under 4,500 feet, and the climate is highly favorable for fruits, as well as for various crops. In Mason and Smith valleys large areas are irrigated for alfalfa, two to three cuttings per year being obtained, and in many cases the cattle find pasturage on these same fields in early spring or late fall after the crop season. There being little or no market for this alfalfa it is fed for dairy purposes or for raising beef cattle. The lack of transportation facilities retards the development of these valleys. The land at present under cultivation is in area almost insignificant with that which might be cultivated by a better supply of water. The amount from the Walker river is nearly all utilized during the latter part of the crop season, and in years of drought there is scarcity for the land now cultivated, as in 1889, when there was large loss, particularly in the second crop of alfalfa. As in the case of the Truckee and Carson rivers, water storage seems to be the main hope of the irrigators, although apparently there is no present prospect of realizing any of the schemes, as the best storage sites are across the line in California. Water for use in Smith valley might possibly be held by a reservoir on or near West Walker river in the lower end of Antelope valley, and in the same way that for Mason valley in the lower end of Smith valley.

The ranches are mainly in the hands of a few persons owning large acreages, and the tendency seems to be to increase the average size of irrigated crop per farm rather than to diminish it. It is almost impossible for a settler to take out a new ditch to supply his land, and the expense of buying rights in an old ditch is too great for a poor man. A large amount of land is held for stock raising or for speculative purposes, so that the population increases very slowly. Along the Carson river in Churchill valley are a few irrigated areas, the principal crop being alfalfa. For these low, level lands there is often an excess of water in the latter part of May or early in June, followed by a drought later in the season. Storage could probably be provided for this flood water by utilizing some of the reservoir sites higher up the stream, in particular that in the lower end of Carson valley in Douglas county. The quartz mills along the river from Empire to Dayton, up stream from these agricultural lands, have first claims to the water, and the efforts of these mill owners to secure an ample supply during periods of drought will be of benefit to the agricultural land below, since the water after being used for power is returned to the river. There is, however, a conflict of interest between the irrigators in the Carson valley above the mills and the irrigators farther down, the development of agriculture in the upper valley tending to decrease the supply for the lower.

Examples of the ditches of this county may be given. The Weston and Campbell ditch, taking water from the main Walker river and carrying it northerly toward Wabuska, is 8 miles long, averages 8 feet wide, and is owned by private parties sharing the water among themselves. The Dayton Ditch Company takes water from the Carson 1.5 miles above Dayton, carrying it out on the south side for a distance of 5 miles, covering land in the vicinity of Dayton. The average width is 6 feet and it cost about $10,000. There are three reservoirs on this ditch, each holding an amount of water equivalent to that usually flowing during 12 hours in the ditch. By this means the water flowing during the night is held for use on the next day. The Hougham and Howard ditch takes water from the Carson river about 16 miles below Dayton and carries it out on the north side for a distance of about 5 miles. The average width is 8 feet and it cost probably $5,000. The water is taken from the river by a permanent dam 6 feet in height, raising the water so that it flows into the ditch. The water in the river at this point has never completely failed, although failure has been reported both above and below.

NYE COUNTY is in south central Nevada, extending from the head waters of streams tributary to the Humboldt southerly to the California line. It embraces a great area of rough mountain ranges and nearly level barren valleys, whose only perennial water supply is from an occasional spring of cold or hot water often charged with mineral matter. In April and May, when the snow melts upon the high ranges, streams are formed which rush down the sides and out upon the valleys, forming short lived lakes or marshes. During these months vegetation springs up and affords excellent pasturage for live stock. Wherever water can be had for cattle to drink there the hardy ranchman has taken up his abode. If there is sufficient water for irrigation, various forage crops are raised for hay for winter feed; also small areas are planted to wheat, barley, oats, and vegetables. Among the mountain ranges are large deposits of mineral wealth, but the difficulty of transportation renders these almost valueless at present.

The principal crop areas are in the northern end of the county, where the altitude is greater and the water supply more abundant. On the head waters of Reese river, which flows northerly through Lander county, there are 20 or more ranches from the source of the river down to Austin. The water in this stream usually begins to fail about the middle of June, and is short at the time when most needed, in July. The altitude of this valley is from 6,000 to 7,000 feet. The seasons vary from one year to another, and irrigation sometimes begins in early April, or in other years on the first of May. The water supply for this valley, as well as for that lower in Lander county, could be improved materially by storage, but it is questionable whether with the present value of products this would be profitable.

In Big Smoky valley, to the east of Reese river, there is a small amount of irrigation from springs and from the creeks which flow in the early part of the year. The seasons, however, are short, and the valley is cold and subject to frosts. In the eastern end of the county, on Duckwater creek and White river, are a few ranches, the altitude here being a little less than in Big Smoky valley. In the southern end of the county is the great Ralston desert, south of this the Amargosa desert, and southeast of this Pahrimp valley, where there are a number of ranches. The altitude of this valley is less than 4,000 feet, and it has a comparatively good water supply in a few localities by the drainage from Charleston peak, which rises to an altitude of over 8,000 feet. The ditches of this county are all small, being taken mainly from springs or from the fluctuating mountain torrents. The Gooding ditch may be given as an example, taking water from the west side of the Reese river. The total length is 2.5 miles, width 3 feet, cost about $250, and area irrigated nearly 200 acres.

ORMSBY COUNTY includes a small area on the western side of Nevada, extending easterly in a narrow belt from lake Tahoe on the west across the Tahoe range and Eagle valley to Pinenut mountains. It is the smallest county of the state, comprising only 144 square miles, the greater part of this being mountainous. It includes the state capital at Carson, and in population ranks third in the state. The agricultural land of the county is mainly on the west side of Eagle valley at an altitude of 4,600 to 5,000 feet. The water supply is derived from streams flowing easterly from the Tahoe range, the principal of which are those in Ash and King canyons, and also Clear creek. A number of small farms are cultivated by the use of several of the cold or warm springs which occur in the valley. The Carson river flows through the eastern part of the county mainly in canyons, and its waters are not used to any considerable extent in this county. A large increase of agricultural area can be rendered possible only by the construction of storage reservoirs mainly to the west of Eagle valley. By providing efficient storage the lands in Eagle valley, especially those on the eastern side, now unutilized and worth from $1.25 to $5 per acre, would be worth from $25 to $50 per acre. There are a number of sites suitable for water storage, but the expense of construction, doubts as to permanence of title to the stored water, and questions as to financial success, as well as the general lack of co-operation among the land owners, have retarded developments in this line. In general it may be said that those irrigators having a supply of water sufficient for present needs do not fully appreciate the necessity of increasing the water supply, while the farmers who do not have ample water are often too poor to materially aid such projects.

Storey county comprises a small triangular shaped area of mountainous country lying south of the Truckee river and east of the Washoe range. It is wholly a mining region, agriculture and stock raising having little or no importance in comparison with the mineral wealth. The population of the county is concentrated at Virginia, the population of that place, namely, 8,806, being nearly one-fifth that of the entire state.

Washoe county extends in a long, narrow strip along the western edge of Nevada from Oregon nearly to Carson, the capital of the state. The principal part of the tilled land, as well as the population, is in the extreme lower end of the county in the vicinity of Reno on the Truckee river. The greater portion of the county north of this point is composed of irregular mountain areas surrounded by nearly level plains made by the sediment deposited from the waters of the ancient lake Lahontan. The soil is rich in many places, but the water supply is scanty and wholly insufficient for the needs of an agricultural population. The county also contains Pyramid lake, one of the two bodies of saline water into which the Truckee empties. The land under cultivation is principally in the vicinity of Reno, on the Truckee meadows, extending southerly up Steamboat valley. Water is derived from the Truckee river and from the small streams which flow easterly from the Tahoe range. The lower lands are wet partially by direct irrigation from ditches, but also in an indirect manner by seepage and by overflow during the spring floods.

In Lemon and Spanish Springs valleys, lying north and northeast of Reno, are thousands of acres of fertile land unutilized for lack of water. It is possible to bring under cultivation a large portion of this rich land by a system of storage of the waters of the Truckee river and by high line canals leading from the river or from these storage works. The expense, however, will be very great, and it is not probable that enterprises will be inaugurated for many years, as much of the land belongs to individuals who can not co-operate in a project requiring enormous capital, and also because many of the necessary storage sites are within the state of California, and are owned by persons who hold them at large prices. The amount of land under irrigation, however, can be greatly increased, first, by a more careful utilization of the amount available from the Truckee, and, second, by making use of smaller storage sites within the state of Nevada, particularly those near the base of the mountains.

The irrigators in this county look toward lake Tahoe as the great reservoir site, and believe that future development will rest largely upon the utilization of this lake; but from the reasons previously given, namely, the relatively great area of the lake and small drainage to it, as well as the fact that the outlet lies in California and is controlled in the interests of lumber men, it seems highly improbable that the county will receive as much benefit from this lake as from smaller projects. Water storage has been begun in a small way by making use of Washoe lake. A stone dam has been built across the outlet and Galena creek diverted by a ditch about 6 miles in length, so that the surplus water of that creek can be turned into the lake. The cost of this enterprise has been a little over $11,000. The principal obstacle was in the fact that the land around the lake is owned by private parties, each of whom was injured to a greater or less extent by raising the surface of the lake. Other storage schemes for holding waters among the foothills have not as yet been attempted on any extended scale.

On the hills and lower mountains is a natural grass most excellent for grazing, furnishing pasturage for large numbers of sheep and cattle. In many of the valleys in which water is too scarce for irrigation the small amount available is sufficient for stock ranging upon the hills. In many places wells have been successfully put down, as, for example, in Lemon valley, where windmills are used for raising water for cattle. Large quantities of alfalfa are cut for winter feed for the stock, two and sometimes three crops being had in a season. It is irrigated three or four times, while the wheat is usually irrigated four times, potatoes five times, and garden vegetables even more frequently.

Measurements of the amount of water in the Truckee river and its tributaries have been made at various points, mainly in the vicinity of Boca, California, and in the vicinity of Reno. This river may be considered as beginning at Lake Tahoe, whose drainage it receives. The outflow from the lake into the river on July 4, 1889, was 136 second-feet. The amount declined rapidly until on August 8 the outflow was 75 second-feet and on August 18 only 49 second-feet.

The first tributary of importance below the lake is the creek draining Donner lake and Cold Creek valleys, entering the Truckee from the north or left hand side. On June 28, 1889, the discharge of Cold creek alone was 11 second-feet, and on July 3 the united discharge of Cold creek and Donner creek was 18 second-feet, a nearly equal amount coming from each valley. On July 6 this total had declined to 10 second-feet, falling off rapidly until in August it was less than 2 second-feet. The total drainage area of both creeks is about 30 square miles.

The next tributary of the Truckee is Prosser creek, which drains Twin valley, flowing into the Truckee a short distance above Boca, Cal., and having a total drainage area at this point of 56 square miles. The discharge during April, 1889, averaged 100 second-feet; in May, 259 second-feet; June, 110 second-feet; July, 17 second-feet; August, 3 second-feet, and September, 2 second-feet, the stream during these latter months being nearly dry. In 1890 the average discharge during April was 340 second-feet; during the latter part of May, 817 second-feet; during June, 580 second-feet; July, 382 second-feet, and August, 102 second-feet, the average from April to August being in the two years, respectively, 98 second-feet and 444 second-feet. The discharge of the Little Truckee, flowing into the Truckee at Boca, Cal., is given in the table on the following page.

DISCHARGE OF LITTLE TRUCKEE RIVER, NEAR BOCA, CALIFORNIA.

(Drainage area, 179 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1890.						
April 2 to 30	2,646	276	958	57,006	5.90	5.86
May	2,867	1,000	1,998	122,914	12.85	11.15
June	1,840	1,005	1,491	89,438	9.36	8.33
July	1,330	295	749	45,975	4.81	4.18
August	390	110	200	12,300	1.28	1.12
September	150	87	97	5,771	0.60	0.54
October	108	70	86	5,289	0.55	0.48

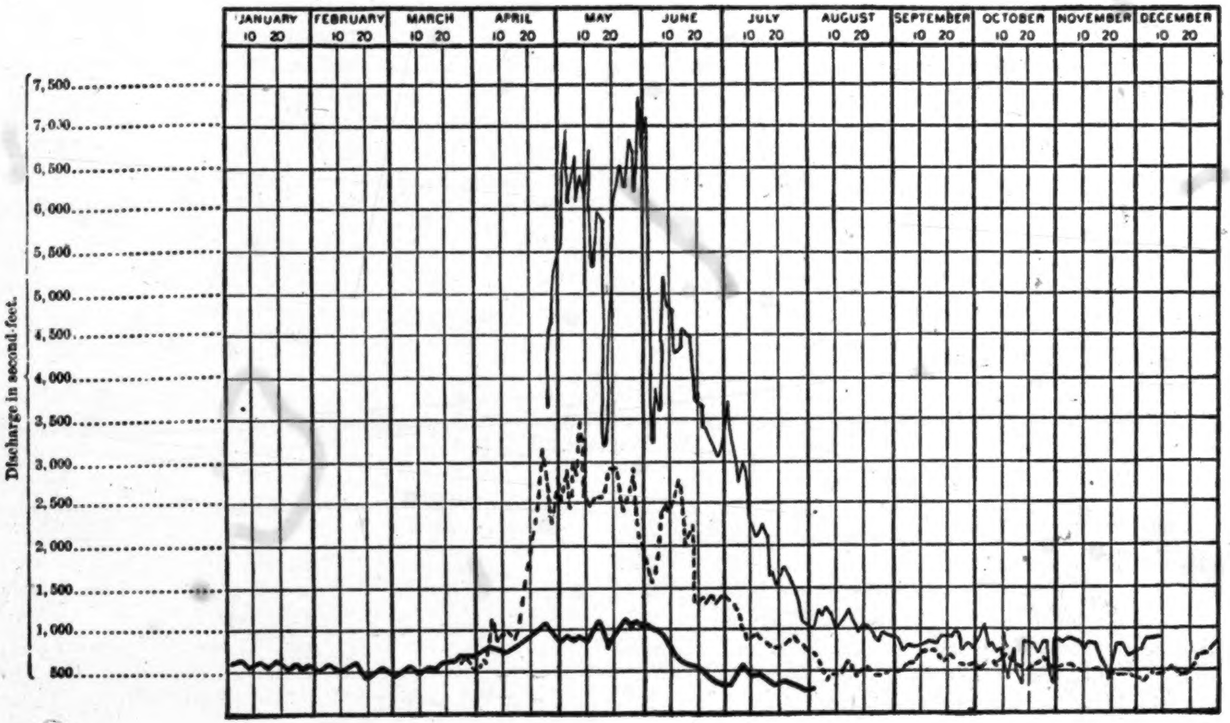
The Truckee river itself was measured near Essex, Nev., during the summer of 1889, giving the following discharges: for May an average of 2,314 second-feet; June, 771 second-feet; July, 278 second-feet, and August, 200 second-feet. The drainage area is 991 square miles. During the following year measurements were made higher up the stream at a point below Boca, Cal., where the drainage area was 902 square miles. Here the discharges were during the last week in March 637 second-feet, averaging in April 2,751 second-feet, and ranging during this month from 580 second-feet to 5,716 second-feet. In May the average was 5,275 second-feet, reaching the maximum of the year of 7,172 second-feet; in June the average was 4,291 second-feet; in July, 1,870 second-feet; August, 736 second-feet; September, 513 second-feet, and October, 555 second-feet.

The discharge of the Truckee was also measured during 1890 at Vista, 8 miles below Reno, the drainage area being 1,519 square miles. This point is below the Truckee meadows and above the lower canyon of the river, thus giving the discharge available for use upon the plains in the vicinity of Wadsworth. In general the discharge here is less than at Boca or points above Reno, from the fact that a large part of the water is diverted for use upon lands in the vicinity of Reno and south of it in Warm Spring valley. (*a*)

---

a In the following diagram the discharge for 1890 is indicated by the lighter continuous line, that for 1891 by the broken line, and that for 1892 by the heavier continuous line. The gaugings are for 1890, 1891, and 1892.

DIAGRAM OF DAILY DISCHARGE OF TRUCKEE RIVER AT VISTA, WASHOE COUNTY, NEVADA.



There are a number of large irrigating ditches in the vicinity of Reno, each taking water from the Truckee and carrying it north or south of the river in nearly parallel courses. The waters of the higher ditches tend to pass by seepage toward the lower, and they probably increase the amount in the lower ditches to a small extent. Taking the principal ditches in order, those on the north side are the Highland, Orr, Sullivan, and North Truckee, and on the south side the Steamboat, Last Chance, Lake, South Side, and Cochran.

The Highland ditch heads about 9 miles above Reno, is 15 miles long, 9 feet wide on top, and 6 feet wide on bottom, with an average depth of 3 feet. Its capacity is estimated to be 32 second-feet, irrigating 1,200 acres. The Orr ditch heads about 4.5 miles west of Reno, and flows in a general northeasterly direction through a portion of the town, the total length being about 9 miles. The top width is 12 feet, bottom width 8 feet, depth 4 feet, capacity estimated to be 77 second-feet, irrigating 2,600 acres. There are two extensions of this ditch, the Orr Eastern ditch and the Orr and Hayden ditch. It is estimated that the land under this ditch requires about 1 miner's inch of water to the acre, a greater amount being used upon new land. Water is delivered to the distributing ditches through measuring boxes, the amount being apportioned according to the estimated number of miner's inches. The pressure is usually taken as being 6 inches, measured above the center of the opening, namely, in the case of a box 10 inches wide, if the gate is raised vertically 2 inches, the water should stand 6 inches above the center of this opening, or 7 inches from the bottom of the box, in order to deliver 20 miner's inches. The ownership is divided into 248 shares, at an estimated value of $200 per share, each share entitling the owner to 10 miner's inches. Many of the shareholders do not own land, but rent the water to other persons.

The Sullivan ditch begins in the town of Reno, and carries water northeasterly about 4.5 miles. The width is about 7 feet, and cost, approximately, $6,500. The ditch is owned by private parties, who divide the water proportionally among themselves. The North Truckee ditch heads about 2.5 miles east of Reno, and runs northeasterly for about 10 miles. The width is 9 feet, and cost, approximately, $5,000. The ditch is owned by farmers who have formed a corporation.

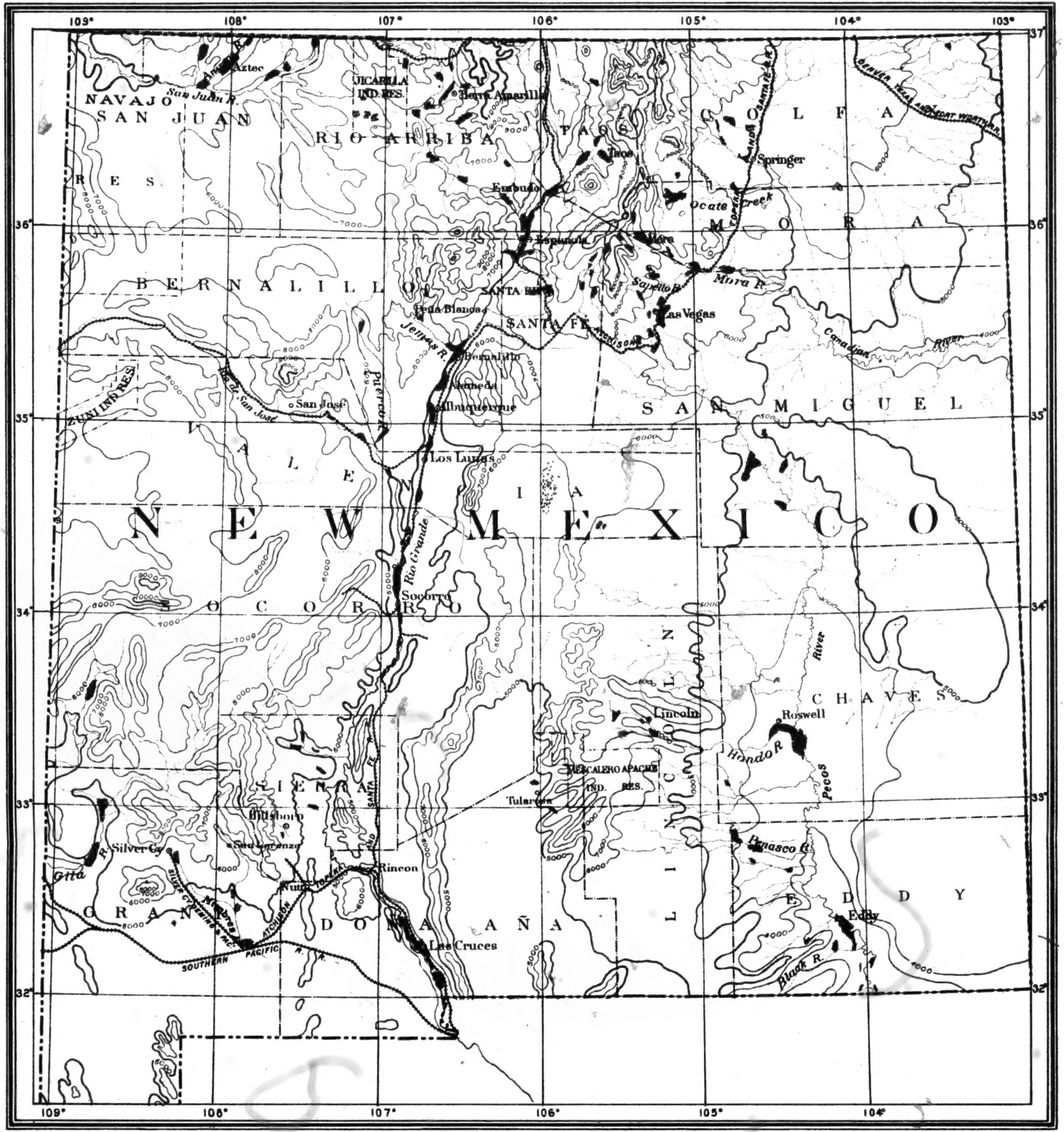
The Steamboat ditch takes water from the south side of the Truckee 15 miles above Reno, and carries it along the river and southerly toward Steamboat valley, a distance in all of over 30 miles. Its capacity is reported to be 65 second-feet. The South Side Irrigating canal heads about 3 miles west of Reno, and carries the water in a general easterly and southerly direction for a distance of 9 miles. The width is 6 feet, and cost about $15,000. The ditch is owned by irrigators, and the water is divided according to the number of shares owned by each individual, one share entitling the owner to approximately enough water to irrigate an acre. The Cochran ditch heads in Reno, and carries the water southerly for about 8 miles. The width is 6 feet, and the ditch cost about $7,000. The first cost of water right is estimated to have been from $5 to $25 per acre, and the annual cost about 25 cents per acre. These statements will serve to give a general idea of the size and cost of the ditches of this county. The laws of the state require that each ditch owner shall file a sworn statement giving a description of the ditch, its dimensions, capacity, grade, land irrigated, and other information from which data can be obtained as to the extent of appropriation of water. The statements regarding the capacity of the ditches are, however, open to question, being in general largely in excess of the amount of water actually carried.

DISCHARGE OF TRUCKEE RIVER AT VISTA, NEVADA.

(Drainage area, 1,519 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1890.						
April 26 to 30	5,610	3,730	4,496	267,512	3.30	2.96
May	7,510	3,200	5,990	368,385	4.55	3.94
June	6,710	3,115	4,162	247,639	3.06	2.74
July	3,730	1,185	2,198	135,177	1.67	1.45
August	1,152	750	952	58,548	0.72	0.63
September 21 to 30	825	570	682	40,579	0.50	0.45
October	1,030	490	742	45,633	0.56	0.49
November	825	400	765	45,517	0.56	0.50
December	....	....	750	46,125	0.57	0.49
1891.						
January	....	....	700	43,050	0.54	0.46
February	....	....	650	36,075	0.44	0.43
March	....	....	650	39,975	0.56	0.43
April	3,115	570	1,523	90,618	1.12	1.00
May	3,285	1,000	2,765	170,047	2.10	1.79
June	2,730	1,280	1,905	113,347	1.39	1.25
July	1,345	730	945	57,928	0.71	0.62
August	690	390	485	29,730	0.37	0.32
September	670	430	558	33,201	0.41	0.37
October	630	510	561	34,389	0.42	0.37
November	550	430	503	29,928	0.34	0.30
December	730	370	508	31,242	0.35	0.30
Per annum	3,285	370	980	709,530	8.69	0.63
1892.						
January	755	450	593	36,469	0.45	0.39
February 1 to 20	636	430	505	29,037	0.36	0.33
March	850	550	723	44,464	0.55	0.48
April	1,030	775	854	50,813	0.63	0.56
May	1,120	590	937	57,625	0.71	0.62
June	1,060	370	628	37,366	0.46	0.41
July	530	210	328	20,172	0.25	0.22

White Pine county is on the eastern side of Nevada, adjoining Juab and Millard counties, Utah. The valleys are at an elevation of 6,000 to 7,000 feet, and the climate in many of them is too cool and frosty for agricultural success every year. The water supply is very limited, and wherever a spring is to be found its waters are employed to their full extent for the irrigation of alfalfa and grass, and to a less extent for produce for home consumption. The population is scattered in the numerous valleys; in Steptoe valley, for example, the ranches are from 1 to 10 miles apart, each being near some small creek flowing from the mountains. The tilled areas are mainly in the vicinity of Cold creek in the northwestern corner of the county, in Newark valley near Eureka, near Cherry creek or Schellbourne in the northern end of Steptoe valley, and all along down toward Taylor in the southern end of the valley. South of Cherry creek are the Campbell ditches, taking water from Warm springs. The total length is 6.5 miles, average width 3 feet, cost $2,000, and area irrigated about 1,200 acres, most of this being hay. This is a fair example of the small ditches owned by the various ranchmen depending upon springs for water supply.


109°
108°
107°
106°
105°
104°
103°
37°
36°
35°
34°
33°
32°
NEW MEXICO
SAN JUAN
NAVAJO
RES.
RIO ARRIBA
JICARILLA IND. RES.
TAOS
COLFAX
MORA
BERNALLILO
SANTA FE
SAN MIGUEL
VALENCIA
ZUNI IND. RES.
SOCORRO
LINCOLN
CHAVES
SIERRA
GRANT
DOÑA AÑA
EDDY
MESCALERO APACHE IND. RES.
Aztec
San Juan R.
Tierra Amarilla
Taos
Springer
Embudo
Ocate Creek
Española
Mora
Mora R.
Sapello R.
Santa Fe
Las Vegas
Peña Blanca
Jemez R.
Bernalillo
Alameda
Albuquerque
San José
Rio de San José
Puerco R.
Los Lunas
Rio Grande
Socorro
Canadian River
Lincoln
Roswell
Hondo R.
Pecos
Tularosa
Hillsboro
San Lorenzo
Silver City
Gila R.
Rincon
Nutt
Mimbres
Las Cruces
Peñasco R.
Eddy
Black R.
Santa Fe R.R.
Denver, Texas and Fort Worth R.R.
Atchison, Topeka and Santa Fe
Silver City, Deming and Pacific
Southern Pacific R.R.
5000
6000
7000
8000
4000

IRRIGATED ■

MAP OF NEW MEXICO SHOWING AREAS IRRIGATED IN 1889.

NEW MEXICO.

Total population (average per square mile, 1.25)		153,593
Number of owners of farms (2.90 per cent of population)		4,458
Number of irrigators (69.20 per cent of farm owners, 2.01 per cent of population)		3,085
Area of territory, land surface (122,460 square miles)	acres	78,374,400
Area irrigated in census year	do	91,745
Area of all farms, 33.39 per cent improved	do	787,882
Cereals raised in census year, including 81 acres in buckwheat and 69 acres in rye	do	61,340
Barley, average production, 23.60 bushels per acre	do	1,484
Corn, average production, 20.45 bushels per acre	do	28,539
Oats, average production, 20.81 bushels per acre	do	9,314
Wheat, average production, 15.72 bushels per acre	do	21,853
Alfalfa	do	12,139
Total value of all farms, including land, fences, and buildings		$8,140,800
Estimated total value of the farms irrigated in whole or in part		$4,677,000
Estimated value of all farm productions (sold, consumed, or on hand) for 1889		$1,784,820
Estimated value of productions, as above, from farms irrigated in whole or in part		$1,174,000
Average size of irrigated farms	acres	30
Average size of irrigated farms of 160 acres and upward	do	312
Per cent of acreage of irrigated farms of 160 acres and upward to total acreage irrigated		21.45
Average size of irrigated farms under 160 acres	acres	24
Average first cost of water right per acre		$5.58
Average annual cost of water per acre		$1.54
Average first cost per acre of preparation for cultivation		$11.71
Average value of irrigated land, including buildings, etc., in June, 1890, per acre		$50.98
Average annual value of products per acre in 1889		$12.80

New Mexico in many respects can be contrasted with Nevada, both in the character of its population and in the methods and results of irrigation. One of the most striking features was the small average size of irrigated farms, 30 acres, these being less than one-sixth the size of the average in Nevada. In this respect New Mexico was surpassed only by Utah, where the irrigated areas averaged 27 acres each. There were very few large irrigated holdings, and these in the aggregate formed only 21.45 per cent of the total area irrigated, this being less than one-half the average for the United States. The average value of products in 1889 was, however, not as high as might be expected, being next to Wyoming, the lowest in the list. The average small farmer, especially of Spanish and Indian descent, has shown little energy or skill, and as a consequence the returns have been small. In cost and value of water rights the territory occupied an intermediate position. The facts concerning these were obtained mainly from modern ditches, the older irrigating works having been built for so many years that it was impossible to obtain even an approximation of their cost.

GENERAL DESCRIPTION.

New Mexico can be divided into three great geographical divisions. On the east are the broad plains, which, extending nearly one-third of the way across the territory, gradually rise to form the plateau which is the base of the Rocky mountains. The rivers which issue upon the plains from the mountain ranges in the northern part of the territory flow eastward and finally unite in the Canadian, a tributary of the Arkansas. South of this drainage, however, the rivers, after flowing eastward a short distance, unite and flow southward into the Pecos, a tributary of the Rio Grande. On the western side of the mountain ranges is the long, narrow valley of the Rio Grande, which traverses the territory from north to south, being confined for a great portion of its way by lofty mountain ranges. In the central and southern parts of the territory, cut off by high mountains from the Great Plains region and the narrow Rio Grande valley, are elevated table lands, perfectly arid, excepting at the edge adjoining the foot of the higher mountains, from which small streams issue. These broad plateaus are useless even for grazing, although their soil could be rendered productive by the application of water. On their margins, however, especially among the western foothills of the Sierra Blanca, agriculture is carried on along the creek bottoms. West of the Rio Grande valley are the high plateaus and mountain ranges, many of them timbered, which form the continental divide, and from which flow the tributaries of the San Juan and Gila rivers, part of the Colorado river drainage.

The agriculture of the territory is governed in its character by these great natural divisions. On the east cattle raising has for years been the only industry, and the farmer has been prevented from entering upon the domain of the cattle kings. It was therefore only among the foothills in the western end of Mora and San Miguel counties that agriculture existed in this eastern division. The Rio Grande valley, however, has from the earliest times been the home of agriculture by irrigation. The original Indian inhabitants, and subsequently the Spanish invaders, took water from the river and its tributaries, not only in very much the same manner as that now prevailing, but even to some extent by the same ditches. There has, in fact, been comparatively little change in many localities along this river within the memory of man. The towns are located at short intervals, wherever the valley widens out to form bottom lands of an extent sufficient for agricultural purposes. Each town or group of farms has its own ditch, and where the population is comparatively dense these small ditches cross and intermingle in apparently the greatest confusion. Owing to the lack of system there is a great loss of water, which might often be avoided by the construction of a single well built canal in the place of the many poorly constructed ditches.

The water is diverted from the river by means of temporary dams, constructed of bowlders and brush. These are often swept away by floods, and thus a loss of crops has at various times occurred, not because of any lack of water in the river, but because a sudden freshet has destroyed the headworks of the ditch. Usually only the lowest lying land has been irrigated, and from lack of drainage this land has in certain localities become so saturated with alkaline salts as to be worthless, resulting in the abandonment of farms, and even in the desertion of some small towns. Artificial drainage, therefore, is for such localities as necessary as irrigation.

Many Mexican farms are long, narrow strips, from 25 to 300 yards wide by about 1,000 yards long, extending from the river up the slope of the hill. As these are divided by inheritance, they are cut lengthwise, so as to give each heir a water frontage, the result being that farms so dealt with eventually become mere strips. Owing to this inconvenient form of the tract to be irrigated there is a considerable loss both of water and of time. The ditches are owned in common by the farmers of each community, and one of the irrigators is annually elected to the position of superintendent of the ditch, his business being to attend to all necessary repairs, and particularly to regulate the distribution of water, which is done largely according to his judgment. Although in the Mexican methods of controlling water there is much to criticise, there is nevertheless one fact which is worthy of commendation, and that is that the control of the water is in the hands of the farmers. The general appearance of shiftlessness and the lack of progress are due rather to climatic and race characteristics than to the defects of the agricultural system, and there is no doubt that security of water right has been insured by this common ownership of the chief source of agricultural wealth, namely, the running water.

Taking the territory as a whole, the water supply of New Mexico is comparatively well distributed, nearly all the counties of the territory having small rivers, and some of them large ones. Unfortunately, however, much of the water is far below the level of some of the best arable land. For example, the Rio Grande, the largest river, at the point where it enters New Mexico, has cut through a great lava covered plateau and flows at a depth of from 500 to 1,000 feet below the general level, a depth so great that by no possible means can water ever be brought upon much of this fertile land. Its tributaries likewise, soon after leaving the mountains, cut through this lava sheet and excavate deep canyons in the soft underlying rocks. Occasionally these narrow canyons open out, as, for example, into the valley of Espanola, where there is a large amount of irrigable land; then, the walls closing in again, the river flows through other canyons until it emerges near Pena Blanca and enters the northern end of Albuquerque valley. This alternation of canyon and narrow valley continues throughout the entire course of the river in this territory, the agricultural land being confined to the bottom lands, or lower mesas, near the river. The investigations of the United States Geological Survey have shown that the lower ends of many of these valleys furnish excellent reservoir sites, where flood waters can be stored for the benefit of the valleys below.

As in the case of Arizona, it may be said that in New Mexico nearly all the water that can be taken out upon arable land by the efforts of individuals or of farmers acting in partnership has now been appropriated, and further agricultural development must come by greater economy in the use of the present water supply and the conservation of waste waters. There are many small streams issuing from the mountains, which sink into the ground within a few miles from the point where they leave their canyons. These streams are not tributary to any river, and the farmers who have appropriated their waters are independent of the actions of other irrigators who may depend upon neighboring streams. The amount of land irrigated by these streams depends entirely upon the care with which the water is used and upon the conservation of the floods. No one outside of this small group of farmers is directly interested in the water.

In sharp contrast to the conditions of irrigation along these small lost rivers are those obtaining in the case of the irrigated lands which depend upon the great river systems of the territory, as, for example, that of the Rio Grande. Here, where the water is in great demand, the action of each individual farmer is of more or less importance to every other farmer throughout this great drainage system, for all alike depend upon the one great source of supply, and waste by one person when the water is in great demand may mean loss to somebody else.

So long as there is water enough for all there is no necessity for regulation or co-operation, but when the time comes that the land under cultivation exceeds the quantity of water that is available for its cultivation, then arises the necessity for a broad co-operation among the farmers along the river and a government by those interested so far-reaching that the rights of each one shall be protected.

Agriculture has increased near the head waters of the Rio Grande until in that portion of the river basin which is in Colorado there is more than three times as much land under irrigation as there is along its entire course in New Mexico. As a result of this, and perhaps also of climatic oscillations, the lower valleys have received less and less water, the drought being especially felt in those counties farthest south. As irrigation increases, however, the scarcity of water can not fail to be appreciated farther and farther toward the north. The farmers in these lower valleys, whose rights date back for an indefinite period, look with apprehension toward the future, fearing that all the water will be absorbed by the newer ditches farther up the river. Water storage in this great drainage basin is, however, not a matter that can be entered upon immediately or without great care. It demands a comprehensive knowledge of the water supply and of the factors by which it is modified, as well as the highest engineering skill. Canals and ditches may be laid out with less care and foresight, their failure or even their destruction involving only the property of their owners; but by weak storage dams the lives of entire communities, to say nothing of property, may be placed in constant jeopardy. The proper location of these works, their financial success, and the necessity that the greatest good shall be done to the greatest number, demand a broad yet detailed knowledge of the topography and agricultural resources of the entire basin.

WELLS.

In New Mexico a number of attempts have been made to obtain artesian water, but in the majority of instances the deep wells, though reaching an abundant supply, have not been successful, in that the water does not rise to the surface and overflow. There is reported to be a well near Springer, Colfax county, delivering water at the surface, and it is possible that attempts lately made in Mora and San Miguel counties have been successful. Near Raton a drilling has been made to a depth of over 1,800 feet without obtaining artesian water. At Las Vegas a well over 1,600 feet in depth has a very slight discharge, and at Santa Fe in a well 360 feet in depth water rises to within 70 feet of the surface. In the vicinity of Roswell, in Lincoln county, a well 207 feet in depth and 1.5 inches in diameter is reported as discharging 10 gallons per minute.

At Deming, Grant county, water is obtained in large quantities by wells 40 feet or more in depth. This does not rise to the surface, but is pumped by windmills, of which there are many in use. An effort has been made to obtain water from greater depths in the hope that it might rise to the surface, and drilling in one case has been continued for 1,000 feet or more. The water is reported to rise within 10 feet of the surface and to be found in almost inexhaustible quantities. Near Fort Wingate, in Valencia county, a well 75 feet in depth is reported as flowing, but the amount is not stated.

VALUE OF PRODUCTS.

The average value of products per acre, as shown in the following table, is usually less on the large irrigated farms, but the operation of this rule is not always apparent in New Mexico, owing to the diversity in the methods of cultivation and in the habits of irrigators. As a rule, the average value of products from the lands of farmers whose names indicate that they have migrated from the eastern states is placed higher than that of the products of farms cultivated mainly by Mexicans, whose holdings are usually of small size, and who also report the average value of their products per acre in very small figures. The standard of living varying so much among the different races inhabiting the territory, a comparison of values and products on a uniform basis is difficult and somewhat unsatisfactory. Both the Mexican and the Pueblo Indian have placed very low estimates on the cost of their ditches and the value of their products, but, on the other hand, the cost of their subsistence is proportionately small.

The average value of products to the acre is greatest in Bernalillo county, containing many small, well cultivated farms, with vineyards, orchards, and market gardens, the produce of which finds a ready sale. Next in importance comes Valencia, with its small farms; then Lincoln, with larger farms, owned mainly by an English speaking people; then Socorro, similar in situation to Bernalillo; then Colfax, Grant, and others. The lowest average value of products to the acre is in San Miguel and Mora counties, where the principal farming area is owned by Mexicans and the water supply is scanty. Next to these comes Donna Ana, where the average under ordinary circumstances should be high, but where it is somewhat reduced, owing to lack of water and consequent loss of crops.

Agriculture, as practiced under the old Mexican system, can not be said to be profitable if account is taken of the labor which is required. The small ditches, often poorly constructed, require an immense amount of labor to keep them clean and in repair, and the water is applied to the land in a laborious, time wasting fashion. The owners of the smaller farms, however, have usually some other occupation, such as herding sheep or cattle, and many of them occasionally earn a small amount as day laborers, so that the time which is spent upon their own small farms may practically be considered as unemployed. It is stated that if they could earn regular wages it would be cheaper for them to buy farm produce than to raise it.

CONDITION OF IRRIGATION IN EACH COUNTY.

NUMBER OF IRRIGATORS, AREA IRRIGATED, FARMS, AND CROPS IN EACH COUNTY IN NEW MEXICO IN 1889.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.	OWNERS OF FARMS. (a)		IRRIGATORS.		Area of counties in acres.	FARM AREA.		Cereals. (Acres.)	Alfalfa. (Acres.)	AREA IRRIGATED.			Average value of products per acre.
				Total number.	Per cent of population.	Per cent of farm owners.	Per cent of population.		Acres.	Per cent improved.			Per cent of area of county.	Per cent of total farm area.	Per cent of land owned by irrigators.	
Total	3,085	91,745	30	4,458	2.90	69.20	2.01	78,374,400	787,882	33.39	61,340	12,139	0.12	11.64	17,98	$12.80
Bernalillo	220	4,643	21	292	1.40	75.34	1.05	5,521,920	54,804	30.11	5,779	463	0.08	8.47	39.11	23.50
Colfax	46	5,994	130	70	0.88	65.71	0.58	4,224,000	128,941	35.11	2,074	1,167	0.14	4.65	7.99	16.44
Donna Ana	275	11,051	40	300	3.26	91.67	2.99	5,754,880	36,004	38.39	5,570	2,165	0.19	30.69	35.08	8.82
Grant	158	5,718	36	294	3.04	53.74	1.04	5,952,000	50,171	24.26	2,448	622	0.10	11.40	19.36	16.32
Lincoln (b)	194	7,789	40	303	4.28	64.03	2.74	16,929,280	47,383	28.09	4,134	1,893	0.05	16.44	24.28	17.48
Mora	348	11,403	33	467	4.40	74.52	3.28	2,560,000	156,730	45.06	9,880	1,812	0.45	7.28	12.25	8.78
Rio Arriba	281	6,368	23	442	3.83	63.57	2.44	4,576,000	25,519	51.74	6,272	356	0.14	24.95	35.05	15.10
San Juan	256	9,510	37	277	14.66	92.42	13.54	3,845,120	44,051	23.06	1,850	1,800	0.25	21.59	23.55	13.34
San Miguel	335	9,163	27	463	1.91	72.35	1.38	8,477,440	84,614	31.80	7,767	625	0.11	10.83	9.04	7.92
Santa Fe	123	1,358	11	207	1.53	59.42	0.91	1,466,880	6,762	44.07	1,742	167	0.09	20.08	51.99	14.22
Sierra	65	1,417	22	88	2.42	73.86	1.79	1,994,240	8,400	20.61	753	263	0.07	16.87	26.01	(c)
Socorro	218	4,798	22	295	3.07	73.90	2.27	9,904,640	35,342	24.61	2,059	281	0.05	13.58	25.80	16.46
Taos	262	6,420	25	293	2.97	89.42	2.66	1,472,000	25,852	55.52	4,787	193	0.44	24.83	27.90	8.95
Valencia	304	6,113	20	667	4.81	45.58	2.19	5,696,000	83,319	14.92	6,226	330	0.11	7.34	22.23	21.08

a Includes owned and hired farms, assuming one farmer to each.

b Act creating Chaves and Eddy counties from part of Lincoln county had not gone into effect on June 1, 1890.

c Value of products not obtained.

BERNALILLO COUNTY is in the north central portion of the territory, the main portion of the county extending from the Sandia mountains westward across the Rio Grande and to the Arizona line, while a small strip reaches from the southeast corner eastward to the head waters of the Pecos. The greater portion of the cultivated land of the county is along the Rio Grande, where there are many towns and small villages on or near the flood plain of the river. The valley is from 2 to 5 miles in width, is exceedingly fertile, and, having an elevation of about 5,000 feet, has a climate favorable to the production of all the various fruits and vegetables proper to the temperate zone. The Rio Grande furnishes an ample supply of water for the land at present under cultivation along its banks, but the methods of taking the water from the river are so primitive that losses of crops frequently occur. The ditches, many of which are of great age, are usually of small size, and are taken from the river at short intervals, each supplying a small town or collection of farms. The water is diverted from the river by rude headworks of brush and stone, which are frequently either partially or wholly destroyed in times of flood, and must be reconstructed or tightened whenever low water occurs.

In addition to the lands in the Rio Grande valley there are irrigated tracts bordering the principal tributaries, as, for example, along the Jemez and its head waters. In nearly every case the amount irrigated is but a small percentage of what could be brought under cultivation by improved methods and by comprehensive systems of water storage and canals. During May, June, and the early part of July there is usually a large excess of water, but from the middle of July, through August, and into September, there is scarcity; considerable trouble is experienced in filling the ditches, and owing to the great number and small size of the latter there is a great loss of water by evaporation and seepage.

On the lower bottom land of the Rio Grande valley much of the ground is saturated, and crops of wheat and other small grains, as well as alfalfa, grapes and other fruit, are raised without irrigation, the water being sufficiently near the surface to moisten the roots. The method of irrigation usually practiced is that of pools or borders. Small ridges of earth are thrown up by hand, inclosing rectangular spaces of from 15 to 20 feet in width and 20 to 40 feet or more in length. Into each of these little rectangles the water is allowed to flow until it forms a small pond. It is then allowed to flow into the next rectangle, and so on, until the whole field is irrigated. This requires a great outlay of time and labor, both in preparing the ridges and in applying the water.

COLFAX COUNTY is in the northeastern corner of the territory, being the most northern county east of the mountains. The agricultural land has an elevation of upward of 6,000 feet and possesses a climate favorable to the development of many branches of agriculture by irrigation. The water supply is derived from the head waters of the Canadian river and to a small extent from those of the Cimarron, both of these streams being tributary to the Arkansas. The greater part of the irrigated land is along the foot of the mountains, depending upon the streams flowing from the higher peaks. The ditches are mostly small, and until recently little attention has been given to the cultivation of the soil, cattle and sheep raising being the principal industries. In the vicinity of Springer is an irrigation system of considerable size taking water from Cimarron creek, a tributary of the Canadian. The main canal is 10 miles in length, 20 feet wide on bottom, and with its laterals covers land between the Cimarron and Red rivers. North of this is another system taking water from Vermejo creek, this canal being 20 feet wide, 12 miles in length, and having about 45 miles of laterals, covering land to the west of Dorsey and Maxwell. The summer floods of the streams are stored in a number of reservoirs located among the hills and out upon the plains. It is also proposed to increase the supply by submerged dams across the stream channels and by artesian wells, the conditions being found favorable in the case of a well located 5 miles southeast of Springer, at the junction of Cimarron creek with Red river. This well is 250 feet deep and is reported to flow at the rate of 0.5 second-feet.

DONNA ANA COUNTY is in the south central part of the territory, adjoining the republic of Mexico. It includes the Mesilla valley, which lies along the Rio Grande, and in which is situated the greater portion of the irrigated land. In the extreme eastern portion of the county, west of the Mescalero Apache Indian reservation, are smaller tracts of lands irrigated by the streams which issue from the mountains, the principal towns in that locality being Tularosa and La Luz. In the valleys along the Rio Grande the supply of water is not at all times sufficient for the area now under cultivation, and during the years 1888 and 1889 it fell seriously short. This scarcity of water was due largely to fluctuations of rainfall, but to some extent to the diversions of water made by the large canals in the San Luis park of Colorado and by ditches in the northern part of New Mexico. In 1890, owing to larger rainfall, the water supply was more satisfactory and the farmers renewed their courage. The quantity of water in the Rio Grande has been measured as it leaves this county and passes El Paso, Tex. (*a*) The fluctuations of the stream are very great and during part of the year the channel is nearly or quite dry, although water can always be pumped from the underlying sands and gravels.

There are few irrigating canals of noteworthy size, the water being diverted from the river by many ditches, which are laid out without engineering skill. On account of the poor alignment, with numerous crooks and turns, sediment is deposited from the muddy waters brought by the Rio Grande, and this must be dug out at frequent intervals and at great expense. From the lack of system contentions are constantly arising between the owners of the various ditches, and there is no economy and little care in the administration of the waters. In the eastern portion of the county are enormous tracts of prairie land, between the Sacramento mountains on the east and the San Andreas range on the west. A small portion of this fertile land can be irrigated by a careful conservation of the waters which issue from many of the mountain valleys.

GRANT COUNTY is in the extreme southwestern corner of the territory, bordering upon Arizona and the republic of Mexico. The Gila river crosses the northwestern part of the county, and the Mimbres river, rising near the central portion of the county, flows southeasterly for about 30 miles, to be lost in ordinary seasons in the sand. The agricultural land lies along the valleys of these two rivers, with the exception of small patches where springs issue at the foot of the mountains, and of other areas on the plains, which are watered by means of pumps

---

a The results of the computations of discharge are shown by the accompanying table:

DISCHARGE OF RIO GRANDE AT EL PASO, TEXAS.

(Drainage area, 30,000 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
May 10 to 31	4,705	2,000	3,116	191,634	0.120	0.104
June	4,400	660	2,638	156,961	0.098	0.090
July	930	0	237	14,575	0.009	0.007
August			0	0	0.000	0.000
September			0	0	0.000	0.000
October			0	0	0.000	0.000
November			0	0	0.000	0.000
December	252	0	71	4,366	0.003	0.002
1890.						
January	280	128	196	12,054	0.008	0.007
February	458	108	290	16,095	0.010	0.010
March	1,140	45	424	26,076	0.016	0.014
April	4,108	470	2,190	130,305	0.081	0.073
May	7,200	3,496	5,771	354,916	0.221	0.190
June	7,200	2,925	4,404	262,038	0.164	0.147
July	2,355	235	854	52,521	0.033	0.028
August	2,497	170	734	45,141	0.028	0.024
September	660	40	176	10,472	0.006	0.006
October	116	40	65	3,997	0.003	0.002
November	610	40	284	16,898	0.011	0.009
December	610	430	535	32,902	0.020	0.018
Per annum	7,200	40	1,327	963,415	0.601	0.044
1891.						
January	715	140	451	27,736	0.017	0.015
February	2,040	470	800	44,899	0.028	0.027
March	4,635	470	1,866	114,759	0.072	0.062
April	8,625	1,040	4,265	253,767	0.159	0.142
May	16,620	8,340	11,852	728,528	0.454	0.396
June	8,340	5,045	6,714	399,483	0.249	0.224
July	6,345	610	2,271	139,686	0.088	0.076
August	1,785	17	662	40,713	0.025	0.022
September	9,480	0	768	45,695	0.030	0.027
October	3,535	560	1,488	91,512	0.057	0.050
November	515	235	341	20,289	0.012	0.011
December	560	190	344	21,156	0.013	0.011
Per annum	16,620	0	2,653	1,928,203	1,294	0.088
1892.						
January	470	155	326	20,049	0.013	0.011
February	830	290	476	27,370	0.017	0.016
March	2,070	390	752	46,248	0.029	0.025
April	7,495	470	3,147	187,246	0.117	0.105
May	10,050	5,305	7,093	436,219	0.272	0.236
June	6,465	560	2,943	175,108	0.109	0.098
July	2,500	0	666	41,082	0.026	0.022
August	140	0	13	800	0.000	0.000
September			0	0	0.000	0.000
October			0	0	0.000	0.000
November			0	0	0.000	0.000
December			0	0	0.000	0.000
Per annum	10,050	0	1,285	934,122	0.583	0.043

run by windmills. An attempt has been made to obtain water from the channel of Mimbres river above Deming by a deep cut or drain to intercept the water supposed to be flowing beneath the surface. So far as can be ascertained the scheme is impracticable, and it has apparently been abandoned, after the construction of 8 or 10 miles of canal.

The principal industries of the county are mining and stock raising, the cultivation of the soil being carried on largely in connection with herding or in the vicinity of the railroad towns and mining camps. The irrigating ditches are small and are usually built by a few owners to supply a cluster of farms. The Mimbres river can not always be relied upon to furnish sufficient water for the land at present under cultivation, and injury to the crops is liable to occur, especially in the month of June. Much of the water which sinks into the ground in the channel of this river as well as on the plains can be recovered by wells and by that means small garden spots are rendered very productive. The windmills, which raise the water both for stock and for irrigation, are reported to furnish a supply for from 1 acre to 6 acres of fruit trees and vegetables.

Lincoln county at the time of taking the census included an area of 26,452 square miles in the southeastern corner of New Mexico. About that time two new counties were authorized, known respectively as Chaves and Eddy, the former being in the northeastern part and the latter in the southeastern part of this area. An examination of the returns shows that of the 7,789 acres reported as irrigated in Lincoln county there were 2,101 acres in that portion of the county to be included in Eddy county and 2,011 acres to be included in Chaves county, leaving 3,677 acres in the remainder of Lincoln county. This county lies within the drainage basin of the Pecos river, the principal tributary of the Rio Grande. The waters of this stream come largely from the west, from streams rising in the Sierra Blanca and other mountains on the western side of Lincoln county and from springs issuing from the limestones which underlie much of the country. On the east side of the Pecos there are no living streams, the plains gradually rising toward the escarpments of the Llano Estacado. As a whole, it may be said that the water supply is large and its distribution favorable for the development of agriculture. In that part of Lincoln county not to be included in Chaves and Eddy counties the principal irrigated areas are in the vicinity of Fort Stanton and of Lincoln, water being obtained from Bonito creek, and in the vicinity of Ruidoso irrigating ditches being taken from Ruidoso creek.

A large number of streams flow easterly from the Capitan, Sierra Blanca, and Sacramento mountains, most of these disappearing in the sands, a few finally reaching the Pecos. Farmers have settled along most of these streams and have diverted the water by small ditches, bringing under cultivation a small part of the arable land. Along the head waters of the larger of these creeks there appears to be an ample supply of water, and it is reported that in the upper valleys some crops are successfully raised without irrigation. Cattle raising is the principal industry and the crops are largely for forage purposes.

In that portion of the county to be included in Chaves county the principal area of land under cultivation is in the vicinity of Roswell, where a large amount of water is obtained from the springs and surface streams. There are a number of small ditches taking water from the Hondo and neighboring streams, and 5 miles east of Roswell is the head of the Northern canal, belonging to the Pecos Irrigation and Improvement Company. This canal follows southerly along the west side of the Pecos river, crossing South Spring river, from which some water is obtained, and extending to or beyond the Feliz river. The bottom width is stated to be 35 feet and the length 25 miles, it being proposed to continue this to a length of 50 miles. About 70 miles southerly from Roswell is the town of Eddy, in the portion of the county to be known by the same name, above which are the main works of the company just mentioned. A dam has been built across Pecos river, raising the water and backing it up for a distance of upward of 7 miles, forming a storage reservoir, which can be drawn upon during the months of drought. The dam, built of limestone, is 1,140 feet in length, 135 feet wide at base, and having a maximum height of 40 feet. The headworks of the canal are on the east side, this being 45 feet wide at bottom. At a distance of 4 miles below the dam the canal divides, the principal branch crossing the river and continuing in a southerly course toward the Texas line. The river is crossed by means of a flume 25 feet in width and 475 feet in length, built at a height of 40 feet above the river. The total length of this branch is stated to be 30 miles, the intention being to extend it to a total length of 55 miles. The east branch is 25 feet wide on bottom and has a length of 20 miles. About 15 miles below Eddy is the head of the Hagerman canal, covering land on the east side of the river below that to be irrigated by the east branch above mentioned. Farther to the south, in Texas, are other canals, taking the excess or seepage water from these systems. Water rights under these canals are sold at the rate of $10 an acre, the annual charge being $1.25 per acre. Besides these large canals there are a number of ditches covering lands along the valleys of the Penasco, Seven Rivers, and Black River, the water supply being, however, relatively small for the lands needing irrigation.

Mora county lies south of Colfax and parallel with it, extending in a narrow belt from the mountains eastward toward the plains. It has the largest amount of irrigated land of any county in the territory, aggregating nearly one-half of 1 per cent of the total area of the county. The principal body of irrigated land is in the Mora valley, along the river of the same name. At the upper end of this valley there is an ample supply of water, but farther down the demand far exceeds the supply, resulting often in disappointment and loss to the farmer. Small reservoirs are in successful operation, but the amount of land which they supply is insignificant. They prove, however, the feasibilty of this method of water conservation. High among the foothills and in the mountain valleys a small amount of dry farming has been attempted, but with little success. Besides the Mora river, there are considerable bodies of land depending upon Ocate creek and its tributaries, but the water supply from this stream is not always sufficient to meet the demands upon it.

Rio Arriba county is situated in the northern portion of the territory, adjoining the Colorado line. It embraces on the west a portion of the head waters of the San Juan river, and on the east it extends nearly to the Rio Grande. On the southeast a prolongation of the county extends across the Rio Grande and thus includes the Espanola valley, where is situated the largest body of irrigated lands in this county. This valley is about 20 miles in length and from 2 to 4 miles wide. It extends from La Joya on the north to San Ildefonso at the southern end, and includes various Mexican towns and Indian pueblos. The Chama enters the valley from the west and joins the Rio Grande, thus adding to the already ample water supply. Next in importance to this valley is that of the Chama, in the vicinity of Tierra Amarilla, on the grant of that name. The greater portion of the drainage basin of the Chama is included within this county. The water supply from this river and its tributaries is usually sufficient for the area at present under cultivation, but it occasionally fails in the months of June and July.

In the extreme northwestern corner of the county, on the head waters of the San Juan, at an elevation of about 7,000 feet and over, there is a small amount of dry farming, and near Tres Piedras, in the eastern part of the county, there are also a few farmers endeavoring to cultivate the soil without irrigation, but with little success at either locality.

In a few places tanks or small reservoirs have been constructed to store the water of certain springs. These have been successful, but the area thus irrigated is insignificant. The necessity of water storage is not as yet generally felt, since the loss of crops for want of water is due usually to the condition of the ditches rather than to a deficient amount of water available. Many of the ditches, especially in the Espanola valley, are of great age, some of them of which the history is known having been constructed as long ago as 1712. The land under these ditches has been divided and subdivided by inheritance, so that the ownership is now very large, and great difficulty has accordingly been found in maintaining the ditches and keeping them clear from sediment. On Nutrias and El Rito creeks, tributaries of the Chama, there has been some loss of crops for lack of water, but taking the county as a whole the water supply is ample for present requirements. At Embudo, above Espanola valley, the Rio Grande has been measured and the quantity of water in the river computed for a number of years. (*a*)

---

a The results are shown by the accompanying table:

DISCHARGE OF RIO GRANDE AT EMBUDO, NEW MEXICO.

(Drainage area, 7,000 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
January	495	379	431	26,506	0.07	0.06
February	576	420	473	26,251	0.07	0.07
March	1,042	537	784	48,216	0.13	0.11
April	4,420	970	2,261	134,530	0.36	0.32
May	5,075	2,443	3,430	210,945	0.56	0.49
June	5,060	1,390	2,922	173,859	0.47	0.42
July	1,105	236	471	28,966	0.07	0.07
August	253	181	206	12,669	0.03	0.03
September	264	184	212	12,614	0.03	0.03
October	324	243	283	17,404	0.05	0.04
November	507	253	366	21,777	0.06	0.05
December	610	364	542	33,333	0.09	0.08
Per annum	5,660	181	1,032	747,070	1.99	0.15
1890.						
January	617	260	437	26,875	0.07	0.07
February	670	344	553	30,691	0.08	0.08
March	1,044	330	682	41,943	0.11	0.10
April	3,220	842	2,083	123,938	0.33	0.30
May	6,071	2,660	4,960	305,040	0.82	0.71
June	5,740	2,768	4,107	244,366	0.65	0.59
July	2,640	920	1,593	97,969	0.26	0.23
August	1,134	636	814	50,061	0.13	0.12
September	1,044	496	545	32,427	0.09	0.08
October	606	523	563	34,563	0.09	0.08
November	690	550	616	36,652	0.10	0.09
December	660	636	648	39,852	0.11	0.09
Per annum	6,071	260	1,467	1,064,377	2.84	0.21
1891.						
January	666	550	586	36,039	0.10	0.08
February	1,000	550	616	34,182	0.09	0.09
March	1,450	735	917	56,395	0.15	0.13
April	5,690	735	2,370	141,015	0.38	0.34
May	8,550	4,520	5,965	366,847	0.98	0.85
June	6,340	4,325	5,040	299,880	0.80	0.72
July	4,130	1,250	2,356	144,894	0.39	0.34
August	1,805	320	933	57,379	0.15	0.13
September	2,025	320	469	27,905	0.08	0.07
October	3,350	225	1,681	103,381	0.28	0.24
November	970	515	778	46,291	0.12	0.11
December	880	340	553	34,009	0.09	0.08
Per annum	8,550	225	1,855	1,348,217	3.61	0.26
1892.						
January	615	440	497	30,565	0.08	0.07
February	700	490	596	34,270	0.09	0.08
March	1,550	700	1,051	64,636	0.17	0.15
April	4,910	860	2,979	177,250	0.47	0.42
May	6,665	4,130	4,890	300,735	0.81	0.70
June	4,715	1,550	3,146	187,187	0.50	0.45
July	1,400	280	538	33,087	0.09	0.08
August	300	152	191	11,746	0.04	0.03
September	165	140	152	9,044	0.02	0.02
October	260	165	202	12,423	0.03	0.03
November	400	243	317	18,861	0.05	0.05
December	490	165	324	19,926	0.05	0.05
Per annum	6,665	140	1,240	899,730	2.40	0.18

San Juan county is in the extreme northwestern corner of the territory, at an elevation of from 5,000 to 6,000 feet. The agricultural land is confined to the northern edge of the county, along the valleys of the San Juan and its tributaries, which receive their waters from the high mountain ranges of southwestern Colorado. The southern portion of the county consists of high plateaus, on which the rainfall is very small, and from which therefore there are no perennial streams. Farming in this county without irrigation is impossible, except perhaps in a few spots on the bottom lands, where corn and potatoes have occasionally matured. The climate is excellent and is reported to be favorable for fruit culture, apples, pears, plums, apricots, peaches, nectarines, cherries, and various smaller fruits attaining great perfection. Beyond this the principal crop is alfalfa, of which there are obtained three and sometimes four cuttings annually, the best results, however, being usually obtained when but three cuttings are made. The settlers in this county, on account of their lack of capital, have been compelled to make use of small ditches, not always satisfactory.

Probably the best agricultural land in the county is that which is at present untouched, lying on the mesas back from the river. This is more nearly level and better adapted to cultivation than that now being farmed, but neither the present owners nor the inhabitants of the county possess the capital necessary to the extension of their ditches to these lands or to the construction of new canals of sufficient size. This county offers perhaps some of the best opportunities in the entire west for the construction and profitable operation of large irrigating canals or systems of ditches, on account of the abundance of the water and of the great extent of arable mesa lands. The Animas river is especially noteworthy for its constant discharge and its large amount of unappropriated water. This stream has a decided fall, and it has also gravelly banks and bed, so that the channel shifts but slightly in times of flood, and there are consequently no great obstacles to be overcome in the construction and maintenance of canal headworks. It is bounded, however, by rocky bluffs, and the construction of canals of any considerable size would involve an outlay of capital probably far in excess of the means possessed by the present inhabitants of the county. The San Juan river also contains a large amount of water in excess of what is needed for the land now under cultivation, but it is even less favorably situated for the construction of irrigation works than is the Animas. The land now irrigated consists of a narrow strip along the bottoms, which is quite uneven, and in its natural state is covered with brush.

San Miguel county is one of the largest in the territory, but the greater portion of it consists of plains too arid for cultivation. The agricultural land is principally in the western part of the county near the base of the mountains, a small amount extending southward along the Pecos river. The water supply of the county is derived from two drainage systems, both of which have their rise in the same range and on the same side of it. The most northerly of these is that of the Sapello river and its tributaries, a portion of the Canadian river drainage, and the second consists of the head waters of the Pecos, which finds its way into the Rio Grande. The Sapello river does not furnish sufficient water for the lands now under cultivation along its course, and there is general complaint of scarcity whenever a dry season occurs. A number of small reservoirs have been successfully constructed, and they would be of great benefit if their owners possessed sufficient capital to enlarge them to a size sufficient to meet the demand for water.

On the head waters of the Pecos there appears to be a greater quantity of available water, but lower on the stream the same want is felt. In the southern part of the county there are many engineering difficulties to prevent the inhabitants from diverting the river successfully upon their lands. In this portion of the county the principal industry is sheep raising, agriculture being confined to small garden patches. Irrigation is, however, carried on to a small extent by means of springs and of tributary streams which enter the Pecos mainly from the east. As in Mora county, there is a little dry farming, especially in the valleys among the mountains, where corn, beans, potatoes, and forage crops are raised.

Santa Fe county, which includes the capital of the territory, is the smallest in area of all the counties in New Mexico. The largest body of irrigated land is on the extreme northern edge of the county, in the Espanola valley. The principal water supply for this district comes from the Nambe river, which flows into the Rio Grande near the Indian town of San Ildefonso. Besides this area, there are in the vicinity of the city of Santa Fe and along Santa Fe creek various small irrigated tracts depending upon the water of the latter stream. The ditches in this county are small and numerous, each supplying a village or group of farms. There is apparently sufficient water for the acreage now under cultivation, loss of crops, whenever it occurs, being generally due either to poor management or to accidents to the ditches rather than to a deficiency of water in the rivers.

Sierra county, as its name implies, is rough and mountainous, and, of all the counties of the territory it contains the smallest amount of cultivated land. The Rio Grande flows through the county from north to south, but for the greater portion of the distance it is in a deep, narrow canyon, with little or no agricultural land along its course. In the mountain valleys to the west of the Rio Grande are scattered tracts of cultivated land, but the water supply is insufficient for their further extension without recourse to storage. During certain seasons of the year there is an ample supply of water, and by the construction of small reservoirs in localities that are admirably adapted for the purpose the area of agricultural land can be largely increased. The principal industry of the county is mining, and next in importance to this is grazing, the higher valleys, so far as concerns the needs of cattle, being well watered and having an abundant supply of forage.

SOCORRO COUNTY includes a large portion of the Rio Grande valley, and extends on the west to the head waters of the Gila, where there is some little land under cultivation. The greater portion of the county, however, is composed of high table-lands and forested mountain ranges; in fact, Socorro county is probably the best timbered county in the territory, including, as it does, the great forest areas at the head waters of the San Francisco river and other tributaries of the Gila. Cattle raising is also an important industry, since the valleys contain excellent pasturage.

The character of the irrigated lands along the Rio Grande is similar to that of Bernalillo county, the water supply, however, being somewhat less. As in the latter county, the losses of crops, when they occur, are largely due to lack of care in maintaining the ditches and headworks. Many of the inhabitants view with apprehension the apparent diminution from year to year of the supply of water, and many forebodings are entertained as to the future of their agricultural operations, for they believe that ultimately in seasons of scarcity all the water will be absorbed by the ditches to the north of them, if not by the great canals in southern Colorado. On the head waters of the Gila, however, where the altitude is about 6,000 feet, there is ample water for all the land under cultivation, and the inhabitants, from their situation, feel assured of a sufficient supply for their future needs. Being in a different territory from that in which the greater portion of the water of the Gila is used, they are under no obligations as to economy in its use or as to the storage of floods.

TAOS COUNTY is in the northern part of New Mexico, adjoining the Colorado line, and extends from the summits of the Taos mountains westward across the Rio Grande. At the foot of these mountains, at an elevation of about 7,000 feet, are large tracts of arable land. Only a small portion of this land has been utilized for agriculture, the unregulated water supply being inadequate for the entire area. The Rio Grande flows in a canyon at a depth of from 600 to 1,000 feet below the general level of the plateau, so that its waters can not be diverted, except to a very small extent upon the narrow flood plains in the bottom of the canyon. Nearly all the streams issuing from the mountains have been utilized by the construction of ditches, which carry the waters to the lands of the Mexican and Indian owners. Taos and Embudo creeks and their tributaries supply water for the greater portion of the land now under irrigation.

In general it may be said that irrigation in this county is of the most primitive character, there having been apparently little improvement or other change during several decades, or perhaps during the entire century. The inhabitants are scattered along the creek bottoms, wherever a small ditch can be taken out from a perennial stream. The principal towns are among the oldest on the continent, and they have had comparatively little growth for many years. The water supply that is easily available may be said to be entirely appropriated, but there are great possibilities depending upon a better conservation of the flood waters, since the greater portion of the level arable land of the county is not as yet under cultivation. Loss of crops from lack of water is unusual, since by long experience the inhabitants have learned to adapt their acreage to the probable supply from the streams. The ownership of the land, especially in the small towns, is greatly subdivided by inheritance, the tracts lying in long, narrow strips. These holdings are so small that the customary unit of measurement is the yard rather than the acre. For example, a man's farm may be given as 1,000 yards long and 30 yards wide, the 30 yards being along the ditch and the 1,000 yards sloping away from it. The local customs as to management of water are very old, having been handed down with the land from past generations.

VALENCIA COUNTY is a long, narrow county, extending two-thirds of the width of the territory, the Rio Grande crossing it about the center at its narrowest part. The principal portion of the irrigated land is along this river, the conditions being in every way similar to those prevailing in Bernalillo county to the north. The principal tributary of the Rio Grande in this county is the San Jose, which flows into the Rio Puerco. A small amount of irrigation is carried on by means of the water of this stream. In the eastern part of the county, to the east of the Manzano range, and at an elevation of about 7,000 feet, corn, oats, wheat, barley, rye, beans, and potatoes are raised without irrigation. The crops, however, are not so good as those raised elsewhere on irrigated land.

OREGON.

[SIXTEEN EASTERN COUNTIES ONLY.]

Total population (average per square mile 1.27)		89,495
Number of farms (11.35 per cent of population)		10,159
Number of irrigators (31.01 per cent of farm owners, 3.52 per cent of population)		3,150
Area (70,528 square miles)	acres	45,137,920
Area irrigated in census year	do	177,944
Area of all farms, 56.11 per cent improved	do	3,537,231
Cereals raised in census year, including 2 acres in buckwheat and 5,796 acres in rye	do	333,921
Barley, average production, 21.61 bushels per acre	do	28,808
Corn, average production, 15.07 bushels per acre	do	6,189
Oats, average production, 23.07 bushels per acre	do	27,482
Wheat, average production, 11.78 bushels per acre	do	265,644
Alfalfa	do	15,740
Total value of all farms, including land, fences, and buildings		$36,183,030
Estimated total value of the farms irrigated in whole or in part		$10,143,000
Estimated value of all farm productions (sold, consumed, or on hand) for 1889		$7,517,370
Estimated value of productions, as above, from farms irrigated in whole or in part		$2,473,000
Average size of irrigated farms	acres	56
Average size of irrigated farms of 160 acres and upward	do	300
Per cent of acreage of irrigated farms of 160 acres and upward to total acreage irrigated		42.80
Average size of irrigated farms under 160 acres	acres	35
Average first cost of water right per acre		$4.64
Average annual cost of water per acre		$0.94
Average first cost per acre of preparation for cultivation		$12.59
Average value of irrigated land, including buildings, etc., in June, 1890, per acre		$57.00
Average annual value of products per acre in 1889		$13.90

GENERAL DESCRIPTION.

The above figures, as stated, apply only to the 16 eastern counties of the state, namely, those lying east of the Cascade range, together with 2 counties in the southwestern part of the state, where irrigation has begun to make headway. These, as arranged in alphabetical order, are Baker, Crook, Gilliam, Grant, Harney, Jackson, Josephine, Klamath, Lake, Malheur, Morrow, Sherman, Umatilla, Union, Wallowa, and Wasco. All comparisons of this state as far as irrigation is concerned apply only to the portions mentioned. With this understanding, it appears that Oregon stands sixth as respects number of irrigators and eighth in the area of land irrigated in 1889. For average size of farms it occupies an intermediate position and in many respects it differs little from Idaho, on the east, either as regards cost of water or value of products. In fact the conditions prevailing in eastern Oregon are a repetition of those throughout the Snake river drainage and the northern part of the great interior basin.

The topography of Oregon gives rise to sharp contrasts in the agricultural possibilities of the state as a whole. The most striking feature is the Cascade range, which, at a distance of about 120 miles from the coast, divides the state into two parts, differing widely in climate and general appearance. To the west of the range the rainfall is abundant, and vegetation flourishes in profusion, while on the eastern side the precipitation is small and barely sufficient for the needs of plant life. The range itself consists of a chain of lofty peaks of volcanic origin, the highest, Mount Hood, rising to an altitude of 11,225 feet. From the plateau on which stand these high, conical peaks the country slopes off toward the ocean, broken, however, by the intervening Coast range, which has an altitude of from 2,000 feet upward. Between these two ranges is the Willamette valley, one of the finest agricultural areas in the United States, possessing a genial climate, an abundant rainfall, and a fertile soil. In the southwestern part of the state there is no large valley between the Cascade and Coast ranges comparable to the Willamette, for the streams issuing from the Cascade range flow westerly to the sea and are bordered by less extensive areas of agricultural land. East of the Cascade range, and occupying the greater part of central Oregon, is a vast lava covered plateau, whose surface has an elevation of from 2,000 to 5,000 feet above the ocean. It is apparently a continuation of the vast lava plains which border the Snake river and cover the greater part of southern Idaho. Into this enormous sheet of lava, the general thickness of which is unknown, the streams of the region have cut for themselves channels of from 100 to 1,000 feet or more in depth, and they flow northerly to the Columbia river through deep canyons or gorges. On this vast plateau the rainfall rarely amounts to over 15 inches a year, nearly all the precipitation occurring in the winter and little or none in summer.

In the northeastern portion of the state, between the Snake and Columbia rivers, is a great irregular mass of mountains, whose structure is at present little known. The summits of these, the Blue mountains, rise to heights of over 6,000 feet. The base of the mass is deeply buried beneath the ever present lava, into which the Snake and Columbia rivers have cut their gorges. These mountains exert an influence beneficial to agriculture, for their peaks, rising abruptly from the plateau, encourage the precipitation of rain or snow, and give rise to many streams of great importance in irrigation. Their mineral contents give employment to a large population, and the grazing upon the mountain slopes adds to the wealth of the country. South central Oregon forms still another topographic division of the state, since it belongs to the great basin region and is characterized by the structure peculiar to that unique area. It contains a number of short mountain ranges, which are in reality blocks of the earth's crust slightly uptilted, the upper surface sloping off gently on one side, while the broken edges present bold faces with cliffs and precipices aggregating from 2,000 to 3,000 feet in height. Between these mountain blocks are the valleys, deeply filled with sediment, the surface being so nearly level that rain and flood waters form vast marshes or shallow lakes.

In eastern Oregon, namely, that part lying east of the Cascade range, there is, as a rule, sufficient moisture two or three years out of five to raise fair crops of wheat and other cereals, the success of such crops depending, however, largely upon the care and skill shown by the farmer, and not merely upon the occurrence of fortunate rains. The character of the soil also has an important bearing upon the abundance or failure of crops, some soils retaining a small amount of moisture for a longer time than others. There is always considerable uncertainty as to the success of the cereals, and there are some crops, as well as small fruits, which are never of value without an abundant perennial supply of water. It may be said, therefore, that in one sense irrigation is not absolutely essential, in that farmers can make a living, although a precarious one, without it. As a result, at all points east of the Cascade range, wherever the opportunity offered of diverting a perennial stream upon a piece of arable land there the pioneer has taken up his abode and has cultivated a small acreage of cereals, a garden patch, and as large a forage crop as he can irrigate. Irrigation has been quietly and gradually introduced and practiced in a simple manner, each farmer building his own ditch. Occasionally a few settlers have joined together to accomplish an undertaking too great for any one alone, and in rare instances outside assistance has been called in, but up to the census year it may be said that irrigation in Oregon was in the earliest stage of development, namely, that of individual effort. That year, however, and the one preceding, were times of unusual drought, and the interest in such matters was greatly stimulated by the investigations into the benefits and possibilities of irrigation. The advantages to be obtained through irrigation canals began to be appreciated, as well as the great increase of land values throughout the arid regions. Many projects, therefore, were set on foot in 1890 looking toward the more complete utilization of the water supply of the eastern part of the state. This is especially the case along the rivers issuing from the Blue mountains, the Wallawalla and the Umatilla, and also as regards the wonderful water supply of Klamath lake and its tributaries.

Not only has irrigation received a stimulus in that part of the state where it is essential but its benefits are beginning to be seen in regions where it is usually considered that there is an abundant rainfall. Even in the Willamette valley irrigation is being introduced in a small way, at present mainly for gardens and orchards, for vegetables and berries, or for the late forage crops, artificial watering being of especial benefit during the months of July, August, and September, when the rainfall is at its minimum. At the same time irrigation is creeping around the southern end of the Cascade range, being already of great importance in Jackson and Josephine counties, and is gaining a foothold in Douglas county to the north, although many of the inhabitants indignantly deny that any such method of agriculture will ever be necessary.

WATER SUPPLY AND PRECIPITATION.

Measurements of the amount of water flowing in the streams have been made at two points in eastern Oregon, namely, on the Owyhee, a short distance above its mouth, and on the Malheur, at Vale. Both of these streams are bordered by lands to which water can be brought and large areas rendered highly productive. The fluctuations in the water supply are, however, very great, and must be carefully considered before any general improvement of present systems of irrigation can be entered upon. The behavior of the water in these streams is in a broad way characteristic of that in other rivers of eastern Oregon, since all the streams receive their supplies from comparatively low mountain areas upon which the snow melts early in the season. In this respect the rivers present a marked contrast to those issuing from the main range of the Rockies or from the Sierra Nevadas, the floods occurring earlier in spring and the summer flow decreasing to a less proportional quantity than in rivers from these latter mountains. The distribution of the water by months is shown by the percentages contained in the table on the following page, exhibiting these in connection with the fluctuations of rainfall. From an inspection of this table it is apparent that in April over one-third of the entire amount of water for the year was discharged, and in March, April, and May three-fourths of the whole quantity. Nearly all of this goes to waste, for in most localities it is too early in the season to begin thorough irrigation.

The distribution of the rainfall in the state has been discussed by General A. W. Greely, Chief Signal Officer, in a pamphlet upon the climate of Oregon.(a) In this report are given tables showing the precipitation and temperature at various points, the facts being shown graphically upon maps. In eastern Oregon there are comparatively few stations at which records of rainfall have been kept for any considerable length of time. At Camp Harney, near Malheur lake, observations were maintained at intervals from 1867 to 1880. The average annual rainfall for 7 full years was a trifle less than 11 inches, and of this amount less than 2.5 inches, or 23 per cent of the whole, fell during the 5 months from May to September, inclusive. At Fort Klamath, situated at the head of Klamath lake and almost immediately at the eastern foot of the Cascade range, the record of rainfall has been kept, with occasional breaks, from 1864 to the present year. The mean annual rainfall at this point, which has an elevation of 4,200 feet, was 22.6 inches, while the amount falling in the 5 months from May to September, inclusive, was 3.3 inches, or nearly 15 per cent of the total. At Dalles, on the Columbia river northeasterly from Mount Hood, the average annual rainfall since 1875 has been 16.5 inches, 2.1 inches falling during the 5 months above mentioned. The rainfall for the extreme eastern side of Oregon is perhaps best shown by the record for Boise, Idaho, which has been kept since 1877, the average being 14.3 inches, 2.9 inches of this amount falling during the 5 months from May to September, inclusive. Combining the rainfall observations at Dalles, Fort Klamath, Camp Harney, and Boise, Idaho, and assuming that the averages obtained represent the monthly distribution of rainfall over eastern Oregon, the percentages of total precipitation shown in the following table are obtained.

AVERAGE MONTHLY DISCHARGE OF RIVERS AND PRECIPITATION IN EASTERN OREGON.

MONTHS.	Discharge of rivers. (Per cent.)	Precipitation. (Per cent.)
January	2.2	16.2
February	7.6	12.0
March	25.9	10.5
April	30.0	8.7
May	19.6	6.3
June	5.4	5.1
July	1.6	1.9
August	0.9	1.3
September	1.0	2.7
October	1.3	7.4
November	2.5	11.2
December	2.0	16.7

The distribution of the rainfall throughout the year is strongly marked. In general it may be said that there are two seasons, the wet and the dry. The greatest amount of rain falls usually in December or January, and from that time onward the rainfall gradually diminishes to July or August, when the drought is at its maximum. In September and October there is a slight increase in the amount of rain, and this continues to midwinter. May, June, July, August, and September can be considered as dry months, while the period from October to April, inclusive, is the wet season, during which from 75 to 85 per cent of the rain falls. Comparing the distribution of rainfall with the river flow, it appears that the point of maximum precipitation of rain or snow is reached in December or January, at least 3 months before the time of the greatest river flow, while, on the other hand, the periods of minimum rainfall and riverflow approximately coincide, occurring in August. The fact that the discharge of the streams does not coincide more nearly in behavior with the monthly distribution of rainfall is due principally to the effect of the temperature. During the winter months a large part of the precipitation occurs as snow, and this remains upon the mountains until melted by the warm winds of spring, causing a general increase in the quantity of water carried by the rivers.

It is evident from the examination of the distribution of river flow throughout the spring and summer that these and similar streams can not be made of the greatest possible use to irrigation until methods are devised for holding back this surplus water of early spring, and keeping it to increase the low water during the period of low water a few months later. Storage reservoirs must be built in all favorable localities, and controlled in such a manner that the waters can be employed by the irrigators all along the course of the river. In order to accomplish this result, however, many engineering difficulties must be overcome and favorable legislation enacted both as regards the construction and maintenance of such works and the distribution of the water thus saved.

LEGISLATION.

Up to the time of the census the laws of Oregon were not favorable to the development of irrigation. The majority of the population live west of the Cascade range, where the rainfall is abundant and irrigation not necessary. The laws regarding water, therefore, have been those suitable to a humid climate, and in the direction rather of

---

[a] Climate of Oregon and Washington territory, Fiftieth Congress, first session, Senate Executive Document No. 282.

preventing diversions from the streams than of favoring the use of the water for irrigation. Of late, however, the necessities of the case have been impressed upon the public mind and legislation favorable to irrigation enterprises has been placed upon the statute books. Irrigators state that their water rights have been in the greatest confusion, and that they have had no protection or security in their possessions, and since in arid regions land values rest directly upon the ability to secure a continuous supply of water the titles to property have been in a somewhat precarious condition. (a)

DITCHES.

The irrigating ditches of the state are as a rule quite small, and have been built by stock raisers to irrigate a few acres on their ranches, or by other settlers who have come into the country with scanty means and have been compelled to make use of temporary expedients in order to obtain a crop. There are very few ditches of large size already constructed and in operation, although a number have been projected. Most of the ditches have been built for a number of years, and their owners do not remember the details of their cost and construction. Taking, however, the statistics as given by irrigators, it appears that there was an independent ditch from some stream for every 200 acres of crop irrigated. The average cost of the small ditches under 5 feet in width was $260 per running mile, of those of 5 feet in width and over and less than 10 feet the cost was $1,060 per mile, and for those of 10 feet and over, $1,300 per mile.

WELLS.

Throughout eastern Oregon, wherever water can not be procured from running streams there has been a general discussion as to the feasibility of obtaining water from wells. Many attempts have been made to obtain water in this way by digging or boring, and in a few instances flowing water has been struck. These instances are comparatively rare, and success appears to be due to some local peculiarity of geologic structure. The largest flowing wells yet reported are those in the vicinity of Baker, being situated in the broad valley through which the Powder river flows. This area is partially inclosed by spurs of the Blue mountains, the main range of which is to the northwest. The depth of these wells is reported to be about 150 feet, and the discharge may be as high as one-fourth of a second-foot, the statements on this point being meager.

Other flowing wells are reported in Gilliam and Wasco counties along the Columbia river, where are a number of large springs, some of which may have been considered as wells by the owners. Attempts made to reach flowing water by drilling through the lava covered plateaus have not as yet been successful, and the probabilities are against it. In the vicinity of the lakes of Harney, Lake, and Klamath counties it is possible that small flowing wells can be found, judging from the similarity of geologic conditions there with those of other parts of the great basin region. It has been found that as irrigation is practiced on the edges of these broad valleys, as in the case of Utah Lake valley and Salt Lake valley, in Utah, the lower gravel beds become saturated, and when pipes are driven on the lower ground to a depth of from 20 to 100 feet, penetrating these gravels, a small, though constant, discharge is obtained. Although flowing wells may not be found on the higher plateaus, yet these drillings can not fail in many localities to reach water of some kind, and if this water should prove to be fresh and palatable, it can be pumped, as is already done in a few localities, furnishing a supply for domestic purposes and for the watering of stock, and even for irrigating small patches of ground. In an arid country even these areas, though insignificant in size, are relatively of great importance to the development of other interests, such as stock raising and mining.

VALUE OF PRODUCTS.

An examination of the average value of products per acre, given in the following table, shows that the supply of water in the census year could not have been ample, but a comparison of these figures among themselves and with those for other states demonstrates that the cause tending to make these averages small prevailed throughout all the agricultural communities. It is a well known fact that farmers as a rule undervalue their products, especially those consumed, and there is a strong presumption that they overestimate the size of the areas cropped. Much of the land, especially in counties where grazing is the chief industry, is but carelessly irrigated. The water is applied to large areas and allowed to make its own way across the fields; the hay crop from this land is given a very small valuation by ranch owners, and since these areas are relatively large the average value of products is

---

[a] In February, 1891, a law was enacted providing for an appropriation of water from lakes and running streams for purposes of irrigation, for the condemnation of lands for right of way of irrigating ditches, for extinguishing the claims of riparian owners, and in general for facilitating the construction and maintenance of irrigating works. The employment of the waters of lakes and streams for irrigation and household purposes or for watering stock upon dry lands is declared to be a public use, and the right to collect compensation for such water a franchise. All existing appropriations of water for beneficial purposes, made in accordance with laws or established customs, are to be respected and upheld to the extent of the amount of water actually appropriated. New canals are to be constructed by the most direct route practicable, and two or more ditches are not to be made through a tract of land when the water can be conveyed in one ditch. All corporations shall supply water to consumers applying therefor, upon the tender of the customary rates and the construction of necessary distributaries, unless there shall be an insufficient amount available. Dues for water become a preferred lien upon all crops raised by its use. Interference with irrigating works is prohibited by penalty, and, on the other hand, corporations are held liable for damages due to neglect or want of strength in structures built by them.

correspondingly small. By multiplying the average value of products per acre by the average number of acres in crop the average annual return to each farmer should be obtained. In the case of Oregon this is approximately $778, which is apparently the average earnings per irrigated farm, excluding the profits from stock raising, which, however, is the principal source of revenue to the farmer.

CONDITION OF IRRIGATION IN EACH COUNTY.

NUMBER OF IRRIGATORS, AREA IRRIGATED, FARMS, AND CROPS IN EACH COUNTY IN OREGON IN 1889.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.	OWNERS OF FARMS. (a)		IRRIGATORS.		Area of counties in acres.	FARM AREA.		Cereals. (Acres.)	Alfalfa. (Acres.)	AREA IRRIGATED.			Average value of products per acre.
				Total number.	Per cent of population.	Per cent of farm owners.	Per cent of population.		Acres.	Per cent improved.			Per cent of area of county.	Per cent of total farm area.	Per cent of land owned by irrigators.	
Total	3,150	177,944	56	10,159	11.35	31.01	3.52	45,137,920	3,537,231	56.11	333,921	15,740	0.39	5.03	15.89	$13.90
Baker	408	31,471	77	455	6.73	89.67	6.03	1,260,800	111,295	54.59	6,629	1,278	2.50	28.28	29.45	12.32
Crook	245	8,618	35	622	19.17	39.39	7.55	5,216,000	176,089	33.92	3,690	1,113	0.17	4.89	9.00	17.91
Gilliam	78	1,037	13	673	18.69	11.59	2.17	1,088,000	269,309	36.44	17,441	357	0.10	0.39	2.07	20.20
Grant	325	18,718	58	624	12.28	52.08	6.40	3,502,080	199,590	42.19	3,205	519	0.53	9.38	14.29	14.34
Harney	240	26,289	110	482	18.84	49.79	9.38	6,784,000	469,813	46.90	2,457	250	0.39	5.60	18.31	13.38
Jackson	169	3,230	19	798	6.97	21.18	1.48	1,843,200	228,055	59.21	24,654	3,479	0.18	1.42	5.81	22.42
Josephine	144	2,598	18	398	8.16	36.18	2.95	1,027,200	71,143	29.98	3,952	310	0.25	3.65	6.61	24.85
Klamath	56	5,699	102	332	13.58	16.87	2.29	3,532,800	137,841	54.68	4,404	74	0.16	4.13	15.68	17.16
Lake	355	25,549	72	372	14.29	95.43	13.63	5,145,600	151,968	75.93	1,898	53	0.50	16.81	20.88	11.37
Malheur	329	22,037	67	378	14.53	87.04	12.65	6,350,040	87,190	43.80	1,761	1,937	0.35	25.27	26.65	10.91
Morrow	45	879	20	700	16.65	6.43	1.07	1,292,800	273,873	80.97	29,981	1,620	0.07	0.32	2.81	36.59
Sherman	8	142	18	373	20.81	2.14	0.45	326,400	150,789	58.94	84,161	80	0.04	0.09	9.51	14.53
Umatilla	148	3,571	24	1,372	10.25	10.79	1.11	1,846,400	526,082	73.04	139,187	2,004	0.19	0.68	6.18	32.59
Union	346	21,947	63	1,104	9.17	31.34	2.87	1,942,400	320,678	56.95	46,144	2,075	1.13	6.84	22.72	19.03
Wallowa	111	4,147	37	603	16.47	18.41	3.03	1,849,600	119,189	40.60	4,246	27	0.22	3.48	16.27	16.17
Wasco	143	2,012	14	873	9.51	16.38	1.56	2,121,600	244,327	61.60	10,111	564	0.09	0.82	5.02	33.73

a Includes owned and hired farms, assuming one farmer to each.

BAKER COUNTY is in the eastern end of Oregon, extending from Snake river to the Blue mountains on the west, and from Powder river on the north southward to the divide between Burnt river and the tributaries of the Malheur. The surface of the county is in general hilly or even mountainous, especially in the western part. The rocks, most of which are of eruptive origin, contain small quantities of gold, and the streams which flow from the Blue mountains to the Snake river pass through rich deposits of gold-bearing gravels. This mineral wealth attracted the earlier settlers, and it was only after the establishment of several important mining camps that stock raising and the cultivation of the soil were undertaken. Placer mining is still carried on whenever there is sufficient water, but its relative importance has considerably diminished. Crops can not be raised in the eastern end of this county without irrigation. The only exception to this statement is perhaps in the case of rye, which, if planted early in the spring, may mature without artificial watering. The water supply for irrigation is not of the best, as the streams depend largely upon the melting snows of the mountains. The altitude of the range is not sufficient to cause the accumulation of great masses of snow, and in some years the precipitation is light. As a consequence of the general low altitude of the mountain masses, the snows often melt early in the spring, causing floods in March, April, or May, before there is need of irrigation. Later in the season, when the demand for water is greatest, the streams become almost dry. Water storage, therefore, is urgently needed, and is already being attempted in a small way.

Powder river flows easterly from the southern spur of the Blue mountains, then turns north into a broad valley and continues along the foot of the range, receiving on its way various tributaries from the mountains to the west. After flowing in this direction for from 30 to 40 miles, it turns abruptly to the southeast and finally enters Snake river. Farmers have settled in the valleys along this river, and water is diverted for irrigation from the tributaries coming in from the west, as well as from the river itself. Nearly all of the ditches are small, and have been built by individual farmers, there being few owned by corporations. Burnt river rises south of Powder river and flows in a general easterly course to Snake river. The sands of this river and its tributaries are especially rich in gold, as are also those of Willow creek, which is still farther to the south, in Malheur county. There are also extensive deposits of auriferous gravels on the low divide between these streams, and the waters of Burnt river have been diverted by long and expensive ditches to work these higher placers. The amount of water available is so small that this kind of mining can be carried on only for from 1 month to 3 months in each year. Farmers have settled along Burnt river and in favorable localities have taken out small irrigating ditches. As is usually the case where miners and farmers use water from the same stream there is more or less complaint on the part of the irrigator that the mining companies interfere with his operations by diverting the water or by overloading it with sediment. The older settlers also assert that the increasing use of water for the irrigation of new land farther up the stream is gradually depriving them of their share, and that they can not raise crops on more than two-thirds of the land formerly tilled.

Crook county is in central Oregon, lying east of the Cascade range and west of the southern spur of Blue mountains. The surface of the country is in general rough and broken, and it is covered by vast sheets of lava, into which the rivers have cut deep canyons. In the western half of the county are extensive tracts of high lands known as the "Desert". Much of the soil of this area is covered by sand, and occasionally rough blocks of lava appear above the surface. The county as a whole is well adapted for stock raising, as the nutritious bunch grass is found almost everywhere, even on the "Desert". Sagebrush and juniper abound, the latter being used for fuel and also for fencing. Few crops can be raised without irrigation. Rye, the principal cereal, is generally cultivated without the artificial application of water, but other cereals are usually irrigated if possible. By summer fallowing, however, fair crops of wheat, oats, and barley are raised on the higher grounds whenever the drought is not too severe. Along the river bottoms, wherever water can be taken out farmers have dug small ditches, and are bringing land under irrigation as rapidly as their means will allow. There are large tracts of higher level lands above the reach of water unless it is held by storage among the hills.

The greater part of Crook county is on the head waters of Deschutes river, which flows northward into the Columbia. A small part of the northeast corner borders on Johnday river, which drains Grant county, and also flows northward, entering the Columbia a few miles above the mouth of the above mentioned river. Deschutes river receives the greater portion of its water supply from the eastern slope of the Cascade mountains, where are a number of lakes, each at the head of a tributary of the stream. Owing to the influence of these lakes or to the gradual percolation of water to the river the amount discharged fluctuates within comparatively narrow limits. It is reported that the height of the river ordinarily does not vary more than from 18 inches or 2 feet during the course of the season. It is possible that some of the waters of this river can be taken out upon the high arid plains along its upper course, and it appears not improbable from the reports of irrigators in the county that a great irrigating system can be profitably constructed along this river. There seems to be no question as to the permanence of the water supply, the fertility of the land when irrigated, and the favorable character of the climate.

The principal tributary of Deschutes river in this county is Crooked river, which flows in from the east, carrying the water which drains from the mountains of the western part of Grant county. The supply of water in this stream is in general large enough for the area of irrigable land in the narrow valleys along its course. The smaller tributaries, however, become nearly, if not quite, dry early in the summer, and without storage are of comparatively little value for irrigation. Under the stimulus of recent legislation a number of enterprises have been undertaken with the object of diverting water from Crooked river or its tributaries. Among these may be mentioned the ditch of the Prineville Irrigation Company, which takes water from Crooked river south of Prineville and runs out on the west side of the stream. When completed the ditch will be 15 miles long and 12 feet wide, and it is estimated to cost $12,000. Work was begun in October, 1890. There are small ditches taking water from Ochoco river, the principal tributary of Crooked river, as well as from the latter stream, and, in short, wherever water can be taken out upon arable land at little expense ranch owners throughout the county have done so. By far the greater acreage irrigated is for forage, since there is very small demand for other products. During the drought of 1888 and 1889 the streams shrunk to a volume so small that only a small portion of the hay crop could be irrigated. As a consequence, the yield was far below the average, and great numbers of cattle perished for want of food.

Gilliam county is in northern Oregon, northeast of Crook county, from which it is separated by Johnday river. It extends along the east side of this river in a comparatively narrow strip from the mountains on the south to the Columbia river on the north. Like that of Crook county, its surface is broken and the principal streams flow in canyons or narrow valleys far below the general level of the plains. In many years crops can be raised without irrigation, and most of the farmers trust to an occasional rainfall to bring these to maturity. Along the valleys, however, farmers are irrigating gardens and small patches of alfalfa wherever a perennial supply of water can be found. The higher lands of the county, being far above the reach of water from the large streams, can not be irrigated except in a few localities where storm water can be held in storage reservoirs. The farmers of the county are endeavoring to cultivate such crops as will require the least moisture. Often, however, they are compelled to bring water for several miles for domestic uses, and it is with difficulty that even this small amount can be procured.

Grant county is east of the center of Oregon, lying between Baker and Crook counties. It is on the west side of Blue mountains, and contains the greater part of the head waters of Johnday river. As in the counties just mentioned, the surface as a whole is broken, the rivers having cut deep canyons, in which they flow at places several hundred feet below the general level. Mining and stock raising are the principal industries of the county, and agriculture proper is slowly gaining in importance. There are no railroads in the county; transportation is difficult and expensive, and the area of arable land is, in comparison, so small that it seems probable that stock raising will for some time remain the principal occupation of the settled population. Very little can be raised without irrigation. In some places rye or barley yields a fair return without the application of water, but, as a rule, it is a matter of considerable risk to cultivate any crop without having an abundant water supply at hand. The altitude of the agricultural lands ranges from 3,000 to 5,000 feet, and thus the climate of a part of this area is so cool that frosts may occur even during the summer months. The principal farms of the county are those along the banks of Johnday river, which are so situated that water from that stream can be brought upon them. Some of this lowest land is flooded by the annual overflow of the river and requires little, if any, artificial watering. Besides the farms on the river, there are a large number of ranches situated upon the creeks which flow from the higher mountains. Water is used on these for raising hay and for the small amount of produce required for home consumption.

The water supply of the county as a whole is good, from the fact that the area of level land is limited, and there are large areas of elevated catchment from which water comes. Johnday river carries throughout the year a large amount of water, but the smaller streams after the spring floods decrease rapidly in size, and many of them become almost, if not quite, dry during the summer season. Farms along the main river, so situated that water can be brought to them, possess a great advantage in this regard over those on the smaller streams. The main branch of Johnday river rises in the mountains on the east side of the county and flows nearly west for about 60 miles, passing through what is known as Johnday valley, containing the principal body of farming land in the county. On its way it receives numerous tributaries which enter the valley from both sides and furnish, at least in the spring, a supply of water for the higher lands. The farming land along the valley averages about 1 mile in width, while that used for grazing is from 10 to 20 miles wide. At the western or lower end of the valley the south fork comes in, and the stream turns almost due north, passing through a spur of Blue mountains. It then receives the waters of the north and middle forks and turning to the west passes out of the county. On the southern edge of the county is a portion of the head waters of Silvies river, which flows south into Harney county. Some irrigation is done from this stream, but the altitude is so great that only the hardier crops are raised.

The earliest ditches were built for mining and are still employed to a large extent for this purpose whenever there is sufficient water. Irrigators use the surplus waters from these ditches, there generally being an abundance until the middle or end of June, but when a time of scarcity occurs they are compelled to pay for the water used. Most of the irrigating ditches have been built by individuals, although along Johnday valley there are cases where farmers have joined in partnership in the construction of irrigating systems. Although there is an ample supply of water in this stream, no attempt has been made to take out a large canal to cover the higher lands on account of the engineering difficulties and the expense involved in the construction of such works in this hilly country.

HARNEY COUNTY is in the southeastern part of Oregon, lying south of Grant county. The greater part of this area, as well as that of Lake county to the west, is within the great basin, the streams flowing into shallow lakes or sinks from which the water escapes only by evaporation, the contained mineral matter tending to accumulate and to make the water saline, similar to that of Great Salt lake, in Utah. None of these lakes are as salt as this great body of water, and in many of them the water is so fresh that it can be used for domestic purposes and for watering cattle. Other lakes, as, for example, Summer and Abert, contain a strong solution of potash and soda salts. An explanation given by Gilbert of the nonsaline character of some of these lakes is that they occupy basins which in a comparatively recent time were completely dry. A very slight change in the climate, as, for example, a small decrease in annual rainfall, would cause these lakes to disappear, while, on the other hand, a slightly increased annual precipitation would fill some of them to overflowing. This is the case with Malheur lake, which in past times has overflowed and contributed water to the Malheur river.

The oscillations of climate indicated by the ancient shores of these lakes are of especial interest as showing that in times past there have been great changes in the water supply of this area. As shown by the beaches, the valleys have been filled with water in some instances to a depth of several hundred feet and have again been completely dry, the climate having apparently been far more arid than at present. This period of excessive aridity was followed by an increase of rainfall, so that again the water filled the valleys to a height even greater than before. Then came a gradual decrease to a second period of aridity, which has continued with small oscillations to the present, the slight changes of this century being almost insignificant in comparison with those which have taken place within geologic time.

On the eastern edge of Harney county the middle and south forks of the Malheur rise in the mountains, forming the rim of the basin, and flow out in a general easterly direction across Malheur county into the Snake river. On the northern side of the county is a low range or detached spur of the Blue mountains. These rise to heights of 6,000 feet or over, and from them numerous streams flow in nearly every direction. Those which go toward the south come out upon the broad Harney valley, after passing through the low foothills, in which are numerous smaller valleys. In time of flood the water traverses the broad plains and finally collects in the lowest parts, forming sinks, the most important of which are Malheur, Harney, and Silver lakes. The waters of these lakes are increased also by streams which come into this basin from the south from Stein mountains, whose altitude is upward of 8,000 feet.

The principal industry of the county is stock raising, a little hay being cut for winter feed, and also some barley, rye, oats, corn, and vegetables being produced for home consumption. There are excellent cattle ranges in the mountains to the north of the county and also on those south of Malheur lake. Comparatively little irrigation is done, and it is mainly from small springs among the hills, the water of the larger rivers being controlled to a great extent by cattle companies and used to flood large areas of meadow. Agriculture proper has hardly been introduced in the county, and irrigation everywhere is carried on imperfectly. Some of the settlers who are too poor to construct ditches have attempted to raise crops without an artificial supply of water, but they have generally failed, and in some instances they have been compelled to abandon their homestead claims. In other cases where a small amount of land was irrigated successfully for a few years, the decrease in the amount of water flowing in the streams during the two years of drought has resulted in such a scarcity of water that these lands could not be irrigated, and they also have been abandoned. There have been disputes concerning the distribution of water, and the owners of the smaller ranches complain that large cattle companies monopolize the present supply and prevent irrigation development.

The crop areas of the county are in the small valleys among the mountains in the northern end of the county, or in Harney valley along the streams near the point where they leave the foothills. There are also ranches along the streams which flow from Stein mountains, in the southeastern part of the county. The principal settlements, however, are to the north of the lakes, which occupy nearly the center of Harney valley. Harney valley contains the most extensive area of nearly level, fertile land in eastern Oregon, and would be capable of supporting large agricultural communities if water could be secured for the irrigation of all of its rich soil. The streams entering it do not furnish enough water to supply even a small fraction of this area. Water can be found in most places at a depth of from 10 to 20 feet, and in quantities sufficient for domestic purposes and for cattle. It is probable that if this water can be raised to the surface by some cheap mechanical means areas of considerable size can be cultivated. At present the land is almost valueless, and the valley is in appearance nearly as wild as when discovered.

The principal stream, coming from the north into Harney valley and emptying into Malheur lake, is known as Silvies river. This is a perennial stream to the point where it leaves the foothills, but beyond this place its channel at times becomes dry. At the point where it enters the valley the discharge is reported to be usually from 50 to 60 second-feet. To reach Malheur lake it must traverse the valley for a distance of about 25 miles, and it can do this only in time of flood. During the irrigating season of 1888 the river flowed for a distance of over 9 miles into the valley and in 1889 it extended only 7 miles. In 1890 the waters reached the lake, but did not continue to do so for any long period. Harney valley is so nearly level that in times of flood the water of Silvies river and other streams spreads out over the surface or subdivides into numerous channels or sloughs before reaching the open lake. During the time of the annual flood therefore it is a matter of no great labor or expense to divert the water by little channels or furrows and cause it to flood large areas, from which crops of hay can be cut later in the season. In times of drought, however, as in 1888 and 1889, these lower level lands do not receive any water, and irrigation can be carried only at points higher on the stream. On the lowest lands in this valley there is, during years of unusual flood, an excess of water in March, April, and May, but by the first of July the supply is always scanty.

Near the head waters of Silvies river is Silvies valley, over 10 miles in length and from 1 mile to 3.5 miles in width. The river flows through the center of this valley and is bounded by bottom lands for the greater part of this distance. On each side are sagebrush plains sloping up to the hills, which are partially covered with the species of pine common to that part of the country. The elevation is about 5,400 feet, and the climate is generally cold and frosty, although during some summers there is no frost for a period of from 2 to 3 months. Irrigation is carried on in this valley for the purpose of raising hay, the greater part of the water supply being owned or controlled by a cattle company. West of Silvies river is Silver creek, which flows southerly and southeasterly toward Harney lake. The water supply, however, is deficient and does not supply the needs of the irrigators depending upon it. In the northeastern part of the county in the vicinity of Drewsey, on the middle fork of the Malheur, considerable irrigation is practiced, mainly by means of water from the small streams flowing from the mountains.

JACKSON COUNTY is in southern Oregon, west of the Cascade range. It thus lies outside of the arid regions of the United States, since the rainfall on the western side of the Cascade range is usually sufficient for the needs of agriculture. Irrigation is carried on to a certain extent, as larger crops per acre can be raised by this means. The principal industries of the county have been mining and stock raising, but, since there is a railroad running through the county furnishing transportation from California to the Columbia river, the cultivation of small grains and fruits has assumed a greater importance. These are successfully raised without the artificial application of water, but it has been found that certain soils, apparently barren and sandy, can be rendered very productive by irrigation. This is especially the case in the cultivation of certain forage plants, alfalfa, timothy, and other native grasses yielding under this method of cultivation a large return on tracts otherwise almost worthless. The climate, like that of all the counties near the coast, is mild and favorable for the production of fruit, many of the orchards being irrigated.

The water supply of the county is large. Nearly all the streams are tributary to Rogue river, which flows in a general westerly direction into the Pacific ocean. The valleys in general are narrow, and are at an elevation of from 1,200 to 2,000 feet and upward. The amount of level land is comparatively small, and it is necessary, therefore, in most cases to build long and somewhat expensive canals in order to cover a large area of irrigable land. With the abundant water supply and genial climate it is probable, however, that large irrigating systems can be profitably constructed in this county. The principal areas at present irrigated are in the vicinity of Ashland on Bear creek, near Brownsboro on Little Butte creek, and near Uniontown and Applegate on Applegate creek. Mining has been carried on principally in the western part of the county, and the waters of the streams have been diverted largely for this purpose. As the mines were worked out, the water has been used more and more for purposes of irrigation. This is especially the case in the vicinity of Applegate, where there are numerous claims to water rights, and large reservoirs have been constructed, furnishing water for many miles of ditches and flumes constructed for the mining companies. This water is easily transferred to the adjacent fields and gardens, causing a rapid increase in the areas irrigated. In the Rogue River valley, in the center of the county, are a large number of streams coming from the steep mountain slopes. The waters are used on areas near Ashland, where the soil is dry and requires thorough irrigation. Also along Little Butte creek the soil and underlying gravel deposits require thorough saturation before agriculture can be made profitable.

JOSEPHINE COUNTY is in southwestern Oregon, west of Jackson county, to which it is similar in many respects. Mining and lumbering are the principal occupations, agriculture being relatively of small importance. The valleys are narrow, and the tilled lands are in general at a distance from the railroad too great to repay the expense of transportation. As in the case of Jackson county, the water supply is large, although there are instances in which it is inadequate for present needs. This is due, however, largely to lack of proper care in distributing and using the amount available. The county lies almost wholly within the drainage basin of Illinois river and Leland creek, both of which are tributary to Rogue river. In all parts of the county crops are successful without irrigation, but it has been found advantageous to use river water on account of the increased productiveness of the soil. The areas irrigated are in general small, and consist principally of orchards and fields of alfalfa or other hay producing plants. By irrigation these forage plants produce a second or third crop in the summer, when otherwise the summer's drought would not permit their growth. The principal areas irrigated are in the vicinity of Waldo, Althouse, and Kerby, on the head waters of the Illinois river; also on Applegate river, below the town of that name, and along Leland creek. Irrigation has developed but little, and it may be said to be still in its infancy. On some of the smaller creeks the older irrigators are already complaining that the late comers do not respect their priority of right, and are diverting waters which should be used by those who first settled the valleys. Thus, even here, in this humid climate the necessity of a systematic distribution of the water is beginning to be appreciated. There are as yet no corporations selling water, and very little, if any, outside capital has been invested in irrigation works. Thousands of acres of good land, however, can probably be brought under irrigation with profit. This is especially the case on the higher lands, which in the latter part of the summer become too dry for successful farming.

KLAMATH COUNTY is in southern Oregon east of the Cascade range. In many respects it is similar to Harney and Lake counties, which lie to the east, but it is unlike them in the fact that its principal lakes have an outlet to the sea. Although it is topographically similar to the great basin region yet the greater part of the county is included within the drainage basin of the Klamath river. A large part of the county, especially in the northern end, contains small lost river basins, that is to say, drainage areas within which the water collects in some small lake or marsh and is gradually lost by evaporation. The Klamath lakes, however, in the southern part of the county, when at a higher level cut a narrow channel through the Cascade range, through which the surplus water now escapes. The principal industry of the county is stock raising, and agriculture proper is making but slow progress. Crops are often raised without irrigation, and in many years wheat, oats, rye, barley, and vegetables are successfully produced, although the yield per acre is only about one-half or one-third that on irrigated land. Irrigation is gradually gaining a foothold and promises a rapid development in the future. There appears to be excellent opportunities for the construction of canals to cover the level lands in the vicinity of Klamath lakes and along Lost river and Tule lake. Irrigation construction has been retarded by lack of capital and by the unfavorable condition of legislation affecting water rights.

The principal stream of the county is Sprague river, which rises in the mountains on the eastern edge of the county and flows westerly into Klamath lake. This river, and especially its middle and south forks, carry a large amount of water, sufficient to irrigate the greater portion, if not all, of the level lands along the stream. South of this is Lost river, which empties in time of flood into Tule lake. Along the course of this stream are a number of large valleys with fertile lands, but the amount of water in the river is not sufficient to irrigate more than a small portion of them. A very small part of the amount at present available is utilized.

The loss of crops following the drought of 1888 and 1889 has caused the inhabitants of the county to look upon irrigation as a necessity, and attempts are being made to increase the area under ditch. There are many localities favorable for the construction of irrigation works, especially in the vicinity of the Klamath lakes, where the soil is especially rich and large crops are raised whenever there is sufficient rain. On the eastern side of the county there are a few small ditches for irrigation, but the land is wet mainly by the overflow of the small streams in the springtime. There is an abundance of water near the higher mountains, but as a rule, wherever even a small crop can be raised without artificial watering, no irrigation is attempted. A few farmers living remote from rivers have been able to do a little irrigation by means of springs. Ditches are usually a mile or so in length, being built by each irrigator to bring water to his own land. For example, one taking water from the south fork of the Sprague river runs along the south side of the river for about a mile, with an average width of 2 feet. The dam in the river is rebuilt each year, as it is destroyed by high water. About 50 acres of hay are irrigated, 20 acres timothy and the balance native grass.

In the western end of the county, however, in the vicinity of the Klamath lakes, are several large irrigating systems. One of these, the Big Klamath ditch, takes water from Klamath lake about 1 mile above the town of Linkville, Oregon. It runs southerly on the east side of Link river to the town of Linkville, and then turns eastward toward Lost River valley. The total length of the ditch is 16 miles, the average width 20 feet, depth from 2 to 3 feet, and the cost was approximately $20,000. The water is taken directly from the lake, the level of which fluctuates but slightly each year. The ditch is owned by the Klamath Falls Irrigation Company, which delivers water to irrigators at the rate, it is stated, of $4 per miner's inch. About 2,000 acres were watered by this ditch in 1889, a large proportion of this being in grain and alfalfa. It is estimated that a miner's inch measured under a 4-inch head will irrigate 1 acre. The water supply for this ditch is far in excess of its capacity, and it is proposed to enlarge it as the demand for more water arises.

The Little Klamath ditch takes water from the lake of that name at a point about 3 miles south of the state line in Siskiyou county, California, and runs northerly through a tule marsh for nearly 3 miles, then through a dry lake bed for 1.5 miles, and thence by a deep cut to Lost River valley, along which it flows northerly for over 2 miles and crosses the channel of Lost river by a flume. After passing through the deep cut a branch of the ditch continues southeasterly about 3 miles down Lost River valley. The total length of the main ditch is 16 miles, average width 20 feet, depth about 2 feet, and slope of ditch nearly 2 feet per mile. The total cost is variously stated at from $20,000 to $40,000. Water is delivered to the users at the rate of $2 per miner's inch per season, or for about $1 per acre, a permanent water right costing $8 per acre. The land with water right is valued at $20 per acre.

Lake County is in the center of southern Oregon, lying adjacent to California and Nevada. It is within the great basin, all of the streams rising in the mountains flowing out upon broad valleys, or being lost in shallow lakes or in the marshes which have resulted from the gradual filling of these lakes. The agricultural settlements of the county are mainly in the vicinity of Lakeview, at the northern end of Goose lake, or near Paisley, along the Chewaucan river. There are also ranches in the vicinity of Summer, Silver, and Warner lakes. The principal industry is stock raising, and the crops are mainly for forage purposes. The climate and soil are capable of producing almost any of the crops of the temperate zone, but owing to the lack of transportation facilities it is evidently impracticable to attempt to raise anything which can not be consumed on the spot. The nearest railroads are from 150 to 200 miles from the towns of this part of Oregon, so that it is unprofitable to export anything except cattle, which can be driven out. During the great drought of 1888 and 1889 the feed for the cattle became so scanty that great numbers perished during the cold weather, the losses being almost incredible.

A few crops, mainly of wheat, oats, barley, and rye, can be raised without irrigation, especially in the higher valleys, but the yield is small and does not compare in quantity with that obtained from irrigated lands. On the lower lands the grain sometimes fills without irrigation, but the kernels are larger and plumper after the application of water to the soil. Hay must be irrigated in order to produce a quantity sufficient to repay the labor of cutting. The methods of irrigation in this and adjoining counties are of the simplest and crudest kind, and for the most part consist in producing large artificial marshes or meadows by causing the spring floods to spread over the level ground. The valleys are nearly level, and the streams after leaving the mountains meander through them, sometimes dividing into several channels, and unless the waters are lost by evaporation they flow to the lowest part of the valley, where they form marshes or shallow lakes. During the spring floods the lakes rise and increase the area of marsh land, and during the summer the waters evaporating retreat and the marsh gradually dries. The irrigators to a large extent imitate this natural process. During the spring floods they cause the water of the streams to spread over the ground by placing temporary dams or obstructions in the streams. Sometimes a few short ditches are dug, but usually the flooding is done by furrows, or by allowing the water to find its own way.

The snow generally begins to melt shortly after the first of February, or from that time on to the latter part of March, according to the lateness of the season. The floods, which begin at that time, spread over the nearly level valleys and cause the grass to spring up. If the water is diverted from these low grounds for any length of time, as a week or more, the soil quickly dries and becomes hard, and the grass withers.

The natural marshes occupying the lower portion of the valley are generally owned by cattle men, who claim that the waters flowing into these marshes should not be diverted at any point above, but allowed to flow undiminished to these lands. Irrigators who have built ditches to take the water out upon dry land above or around the marshes have been restrained from so doing under what are known as the riparian laws, the effect of which is to prevent interference with the natural flow of the streams. In this way the owners of the marshes preserve them as meadows, although the same amount of water which floods them annually could probably be used to far greater advantage upon higher lands by the construction of systematically planned irrigating ditches.

The valley about Goose lake is the best watered of any in the county, and is consequently most thickly settled. There the crops in ordinary years do fairly well without irrigation, but in times of drought irrigation is necessary to prevent a failure. There is an abundance of water flowing from the surrounding mountains into the lake, much of which can be utilized only by the construction of reservoirs and canals. The mountains are well timbered and afford an excellent summer range for stock. In Drew valley, about 15 miles northwest from Goose lake, are ranches raising hay by means of water taken from the creeks. Each irrigator has his own small ditch, and the water is divided according to circumstances. The meadows around Goose lake, which are wet by the seepage and overflow, fluctuate in area according to the rise or fall of the lake. In 1889 the lake was unusually low, there being less water than there had been for many years previous. As a result, there was considerable loss of crops in the vicinity, and during the succeeding winter thousands of cattle perished owing to the diminished supply of forage.

In Warner valley, which lies east of Goose lake, are extensive marshes created by the annual overflow of Warner lake. The greater part of this area is held as swamp land by cattle owners. In the northern end of this valley is a large body of desert land, some of which may possibly be irrigated by means of canals, which at the same time would reclaim a great portion of the swamp land. These canals and necessary reservoirs would be very expensive. East of Warner valley is a mountain block presenting a precipitous face toward the lake, but having a gentle slope toward the east. This slope affords fine grazing lands, watered by numerous springs which flow out and gradually disappear into the desert.

Beyond the mountains to the north of Goose lake is Chewaucan valley, watered by the river of the same name, one of the most important streams of the county. This river rises in the wild, rugged region between Summer and Goose lakes and, cutting through one of the uplifted mountain blocks, it enters the valley to the west of Lake Abert. Here its waters are lost in a great marsh, which was at some former time a shallow lake, but is now filled by sediment brought in by the running water. The town of Paisley is located at the point where the river leaves the mountain gorge through which it has cut, and where the valley begins to widen. Northerly from this town there are reported to be about 20,000 acres of excellent sagebrush land to which the waters of the Chewaucan might possibly be conveyed. Also surrounding the great marsh on the east and west is much good farming land needing water. Irrigation companies have already been formed, and probably in a few years all the available water of the Chewaucan will be used.

At the south end the upper marsh narrows, and a stream flows for about 1.5 miles between sagebrush flats and spreads again, forming the lower marsh. It is estimated that these two marshes contain approximately 19,000 acres. It is highly probable that by careful use of the water upon the higher lands much of this marsh could be reclaimed and cultivated. The overflow from the marsh land cuts through a second uplifted mountain block into the valley beyond, where it is lost in Lake Abert, the waters of which are strongly saline.

Besides Chewaucan river there are several streams flowing into these marshes. These come mainly from the southwest side of the valley, and their waters are now all appropriated, as are also those of Crooked creek, which flows into Lake Abert. Probably no more land can be irrigated from these except by the construction of reservoirs. Northwest of Chewaucan valley, and in about the center of the county, is Summer lake. The agricultural land is mainly in a narrow strip along the west side of the lake and at the foot of a precipitous mountain mass from which many small streams flow. These are used for irrigation, although the land, on account of its proximity to the mountains, is not very dry. On the east and north of Summer lake, however, the land is extremely arid and consists of sand hills and alkaline flats. There are a number of large springs here, some of the water being used for irrigation.

Silver lake is northwest of Summer lake, and, unlike the latter, its waters are fresh. In 1880 the lake averaged about 10 feet in depth, but in 1889, on account of prevailing droughts, the bed was dry.(*a*) The streams entering this valley are diverted as they leave the canyons by each land owner, and are held by dams, ditches, and levees on as great an area of land as possible. The natural meadows have thus been extended and some sagebrush land brought under irrigation, the natural swamps being partially dried. Several ditches have already been constructed

---

a Its area in 1891 was from 12,000 to 15,000 acres and depth about 5 feet.

to convey water upon the fertile sagebrush plains, where there are perhaps 10,000 acres susceptible of irrigation, but as a whole there is a general lack of system, and much of the best land is injured by excess of water. By properly conserving the water in reservoirs and carefully utilizing it large areas could be brought under irrigation, and possibly a portion of the bed of the lake kept dry, affording excellent farming lands.

MALHEUR COUNTY is in the southeastern corner of Oregon, extending in a north and south direction along the eastern boundary for a little over half the width of the state. The Snake river flows along the northeastern side of the county and receives the waters of the streams of this part of the state not lost by evaporation. The Owyhee river, rising in Nevada and southwestern Idaho, flows northerly through the county into Snake river, and the Malheur river crosses the county from west to east, emptying a short distance north of the Owyhee. The tilled lands are mainly in the northern end of the county, along the Malheur and its north fork, and on Bully and Willow creeks. There are also some farms near the mouth of the Owyhee, and settlements of considerable size in Jordan valley, which lies farther toward the southern end of the county, the upper part of this area being in Owyhee county, Idaho, and known as Pleasant valley. There are other ranches scattered among the mountains throughout the county wherever there is a sufficient water supply for cattle and for irrigating crops of hay and grain.

The water supply of the county, taking it as a whole, is below the needs of the present population, for, according to the statements of the farmers, there has not been during the past few years an amount of water sufficient to irrigate the areas usually tilled or from which hay crops have been cut. This was notably the case in the summers of 1888 and 1889, when unusual drought prevailed throughout this portion of the country. In these years there was great suffering among the irrigators living along the lower part of the streams, where, owing to the diversion made above, there was little or no water. The Malheur receives a large portion of its water from the low mountain ranges on the north and northwest sides of the county. These mountains are so low, rarely reaching heights of over 6,000 feet, that the snows of winter melt rapidly in the spring, causing the floods from the rivers to occur very early in the season, so that the greater part of the water has passed down the stream before the farmer begins irrigation. The channels of the streams are generally broad and sandy, and after the flood season the greater portion of the water is gradually lost by seepage and evaporation as it passes over the pervious beds. The irrigators near the head waters are usually able to secure water throughout the season, while those situated near the mouth of the Malheur can not obtain an amount sufficient for their needs.

On the Malheur river settlements now extend from the mouth for 100 miles, and in this distance there are at least 20 ditches of considerable size. Those highest on the stream do not have a surplus of water after the end of June, and those lower are nearly, if not quite, dry. There is less water during the latter part of the crop season at Vale, about 15 miles above the mouth of the stream, than at Juntura, about 60 miles above. The valley of the lower Malheur is broad, and is bounded by low foothills having a rich and fertile soil, capable of producing large crops if water could be brought upon it. The bottom lands are wide, extending along each side of the river and up Willow creek and other tributaries. With the present water supply only about one-half of the low land can be cultivated. During high water the bottoms are wet by seepage from the river, so that hay can be raised with little or no artificial irrigation. In the Malheur valley, as well as throughout the county, the ditches in general are poorly constructed, having been hastily built to supply the immediate needs of the farmers. There is need of a better system of ditches or canals by which larger areas of land can be covered with greater economy. The majority of the irrigators are principally interested in stock raising, the largest crop being hay for winter feed, general agriculture not being as yet highly developed.

In the lower Malheur valley and also along Willow creek are a large number of wells furnishing an unfailing supply of water at a depth of 20 to 30 feet below the surface. Many windmills have been erected for the purpose of raising this water for cattle, the excess being allowed to flow upon the ground, irrigating small areas of land. It is probable that in the aggregate several hundred acres are cultivated in this manner. The supply of water appears to be so great that it is probable that larger pumps can be used to advantage in bringing it to the surface. The cost of fuel is so great that it has not become profitable to employ steam power. Along Willow creek are several ditches, each supplying water for one or two ranches. Several of the irrigators report that in 1889 on account of the drought there was little or no water to be had. Away from the immediate vicinity of the stream, near the little settlement of Dell, there is no farming, and the entire country on every hand is a bleak, barren desert, with no vegetation save an occasional tuft of bunch grass or clump of sagebrush. The soil is rich, however, and thousands of acres of excellent farming land can be brought under cultivation if an abundant water supply can be had. Higher, near the mountains, are many springs whose waters seldom flow to any great distance, being soon lost in the pervious basaltic rocks. All this land is now valueless, except as a range for cattle.

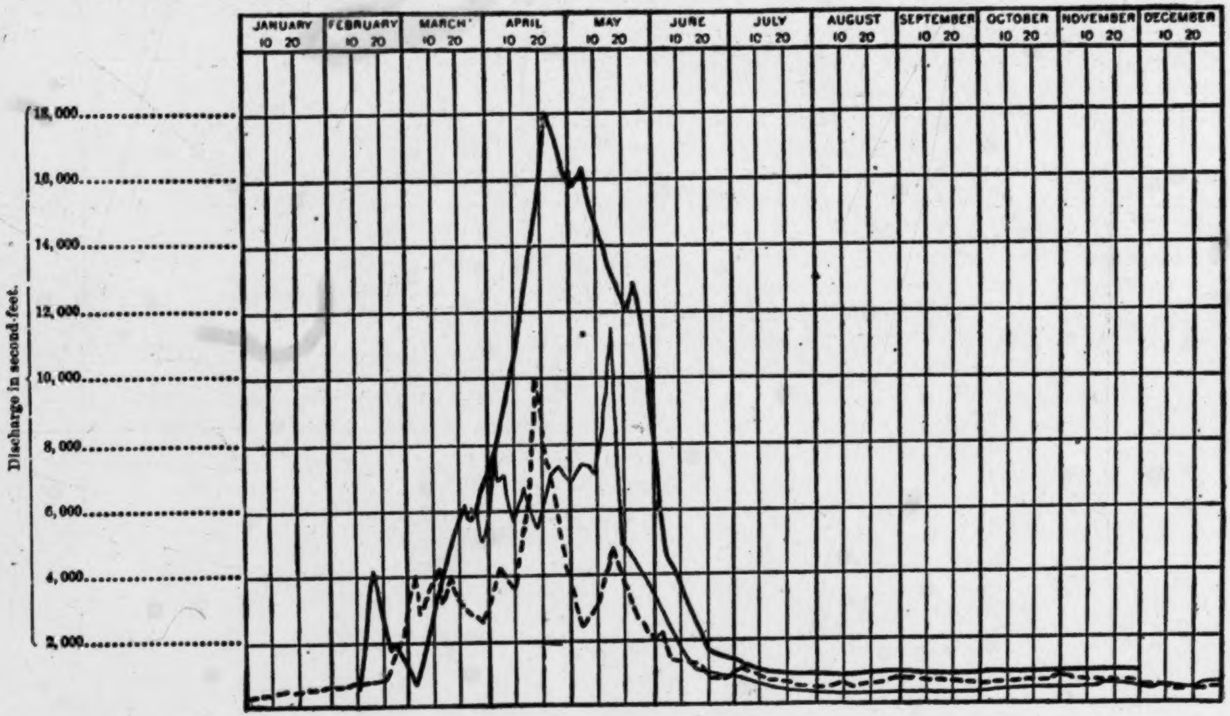
The ice on the rivers generally breaks in February or early in March, and the floods soon follow. Water is usually turned into the ditches about the 20th of March or the early part of April and used until October or November, or until the streams become dry. Malheur river has been gauged at Vale. The maximum discharge was in March, 1890, when the river carried 4,445 second-feet. It has been estimated that the maximum flood of the past 7 years has amounted to from 7,000 to 8,000 second-feet. During the summer months the river is practically dry below Vale, the water being taken out by a large number of irrigation ditches higher up stream.(*a*) The quantity of water in Owyhee river has been ascertained by gaugings made below the canyon and about 4 miles above the mouth of the river, this point being about 20 miles south from Ontario. The results of the measurements show that the average discharge for nearly three years is over 2,100 second-feet, the amount varying from 200 second-feet in times of drought to 18,000 second-feet in flood. The daily fluctuations are best shown by the accompanying diagram, one of the most noticeable features of which is the early occurrence of the spring floods and the rapidity of their rise and fall.

Morrow county is in northern Oregon, between the western spur of Blue mountains and Columbia river. The surface in general is hilly or rolling, but for the most part is covered with rich sandy loam. Crops of all kinds are raised without irrigation, although in some years, owing to drought, the yield is small. The county is drained by a number of creeks which flow northerly into the Columbia river. These carry but little water during the summer, and will not yield a supply sufficient for irrigating canals without the use of storage reservoirs. Wherever possible, however, ditches are now taken out from these streams upon the narrow strip of farming land along the

---

[a] In the diagram the discharge for 1890 is indicated by the lighter continuous line, that for 1891 by the broken line, and that for 1892 by the heavier continuous line. The results of observations appear in the tables following.

DIAGRAM OF DAILY DISCHARGE OF OWYHEE RIVER AT RIGSBYS, MALHEUR COUNTY, OREGON.



DISCHARGE OF MALHEUR RIVER AT VALE, OREGON.

(Drainage area, 9,000 square miles.)

Months.	Discharge in second-feet.			Total for month in acre-feet.	Run-off.		Months.	Discharge in second-feet.			Total for month in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.		Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1890.							1891.						
March 20 to 31	4,445	1,840	2,912	179,088	0.34	0.29	January	115	70	88	5,412	0.01	0.01
April	3,450	2,180	2,770	164,815	0.31	0.28	February	2,820	80	319	17,704	0.03	0.03
May	2,890	590	1,627	100,060	0.19	0.16	March	1,400	260	703	43,234	0.08	0.07
June	520	120	254	15,113	0.03	0.02	April	665	325	511	30,404	0.06	0.06
July	90	25	48	2,644	0.005	0.004	May	325	115	217	13,245	0.03	0.02
August	25	15	17	1,011	0.002	0.002	June	185	45	78	4,641	0.01	0.01
September	15	15	15	893	0.002	0.001	July	40	20	30	1,845	0.003	0.003
October	62	15	44	2,706	0.005	0.004	August	30	20	26	1,599	0.003	0.003
November	150	70	118	7,021	0.013	0.012	September	25	20	23	1,368	0.003	0.003
December	115	62	83	5,105	0.009	0.008							

bottoms. The supply, however, often becomes scanty by the middle of June; the channels sometimes becoming dry after that time. The farmers are compelled to trust to the rainfall, as from unfavorable topography and lack of abundant water supply they can not irrigate. They recognize the benefits of irrigation, for it is carried on in a sufficient number of places to show that the soil is wonderfully productive. The summits of the Blue mountains at this point are too low to yield an abundant perennial supply of water, and if artificial watering is to be done recourse must be had to storage of the spring floods. Attempts have been made to secure artesian water, and at Heppner a well was sunk to the depth of 650 feet. Water can be pumped from this well at the rate of from 40 to 60 gallons per minute, but it does not flow. The success of the farmers depends to a large extent upon the condition of the ground at the time of the snow storms of winter. For example, in the winter of 1884–1885 the soil was not frozen when the snow fell. As a consequence, the ground received a thorough saturation, contributing to the success of the crops of the succeeding year. In the winter of 1887–1888, on the contrary, the surface of the ground was frozen at the time the snow fell, and in early spring the water flowed away rapidly, leaving the soil underneath dry. The evil effects of the succeeding drought were thus intensified, and as a result the crops were almost a failure.

SHERMAN COUNTY includes the comparatively small area south of the Columbia river, between Johnday and Deschutes rivers. The surface in general is level, although deeply cut in places by the streams, which flow in canyons at a depth of from 100 to several hundred feet. The soil is a rich, sandy loam, ranging in depth from 3 to 50 feet, in most places completely concealing the underlying lava. It apparently has the property of retaining moisture well, and thus, although the rainfall is very small during the summer, nearly all kinds of crops are successfully raised without irrigation. It would be almost, if not quite, impossible to bring water upon most of this rich land on account of its relatively high elevation. About the only irrigation carried on at present in the county is on low lands near the Columbia, where gardens and fruit trees are wet by means of the waters from springs which issue from the cliffs, or from the waters of some small stream. The results obtained at these places demonstrate the great benefits to be derived from thorough systems of irrigation, and lead many of the farmers farther inland to discuss the advisability of attempting to introduce irrigation in their own localities. During the drought of 1888 many of the crops were a complete failure, and the matter was thus more strongly forced upon their attention. The water supply for domestic purposes is often poor, and many of the farmers are compelled to haul water for long distances during certain months of the year. In some places wells reach water at a moderate depth, as, for example, at Wasco, where it is reported that an ample supply is found at a depth of from 20 to 40 feet beneath the surface.

UMATILLA COUNTY is in northeastern Oregon, west of Blue mountains, extending from the summits of this range westward to the Columbia river. The eastern part of the county adjoining the mountains is rough and broken, but the surface becomes more level on approaching the river. The average rainfall is sufficient to produce

DISCHARGE OF OWYHEE RIVER AT RIGSBYS, OREGON.

(Drainage area, 9,875 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1890.						
March 26 to 31	7,330	5,190	6,140	377,610	0.72	0.62
April	8,225	5,395	6,558	390,201	0.74	0.66
May	11,230	3,010	5,913	363,649	0.69	0.60
June	2,850	620	1,403	83,478	0.16	0.14
July	560	200	343	21,094	0.04	0.03
August	200	170	179	11,108	0.02	0.02
September	170	170	170	10,115	0.02	0.02
October	170	170	170	10,455	0.02	0.02
November	280	200	221	13,150	0.02	0.02
December	360	280	309	19,004	0.04	0.03
1891.						
January	400	320	360	22,140	0.04	0.04
February	3,265	450	932	51,728	0.10	0.09
March	4,335	2,600	3,313	203,649	0.39	0.34
April	10,000	2,900	4,984	296,548	0.56	0.51
May	4,600	2,075	3,114	191,511	0.36	0.31
June	2,150	500	1,267	75,396	0.14	0.13
July	800	240	448	27,552	0.05	0.04
August	320	200	232	14,268	0.03	0.02
September	360	280	317	18,861	0.04	0.03
October	360	280	325	19,987	0.04	0.03
November	400	320	376	22,372	0.04	0.04
December	320	320	320	19,680	0.04	0.03
Per annum	10,000	200	1,332	963,680	1.83	0.14
1892.						
January	320	320	320	19,680	0.04	0.03
February	4,165	320	1,250	71,875	0.14	0.13
March	7,500	630	3,900	239,850	0.45	0.39
April	18,000	7,500	13,466	801,227	1.52	1.35
May	16,400	6,700	13,082	804,543	1.53	1.31
June	6,230	1,200	2,980	177,310	0.34	0.30
July	1,100	700	948	58,302	0.11	0.10
August	700	560	594	36,531	0.07	0.06
September	560	500	506	30,107	0.06	0.05
October	700	500	570	35,055	0.07	0.06
November	800	700	783	46,588	0.09	0.08
December	800	800	800	49,200	0.09	0.08
Per annum	18,000	320	3,268	2,370,268	4.51	0.33

large crops of the cereals, but an occasional drought, as in 1888, has proved destructive. The precipitation during the summer is so small that fruit trees do not always flourish, and irrigation has been used for fruit trees as well as for gardens and meadows. The water supply of the county is comparatively large. The waters flowing from Blue mountains form two rivers, the Wallawalla on the north and the Umatilla in the center of the county. The banks of the first named river are in general low, and water has been diverted by many small ditches leading from the main river and its tributaries and irrigating the bottom lands in the vicinity of Milton. There have been no large systems constructed, but each irrigator has dug his own ditch or joined with one or two neighbors in so doing. The Umatilla river offers many advantages for the construction of irrigating canals, and a number of projects are on foot, some of them involving the expenditure of large capital, in order to irrigate land in the vicinity of Pendleton and at points along McKaye creek and the lower course of Umatilla river.

Along the foothills there is a belt of land relatively humid where crops of nearly all kinds are raised without irrigation. Beyond this is the subhumid area, where occasionally good crops of wheat and oats are obtained, and at still lower altitudes adjacent to the Columbia river are the lands which may be designated as arid. It is in these latter localities that irrigation will be especially valuable. Plans have been made for diverting the water of Umatilla river by a canal heading at a point about 18 miles above Pendleton. The water will first be conducted through a flume for about 4 miles and then by a side hill canal, the line following up Wild Horse creek, then crossing and ending at a point about 2 miles north of Pendleton. Another project, that of the Columbia Valley Land and Irrigation Company, involves the diversion of water from the lower part of Umatilla river at a point near Echo, the canal line, covering lands to the west, crossing Butter creek at about the sixth mile. Beyond this creek is a place where water can be held in a large depression, thus furnishing a supply for lands further to the north. On the upper waters of McKaye creek are localities reported to be favorable for the storage of flood waters, and the Blue Mountain Irrigation and Improvement Company proposes to utilize one or more of these, taking the water thus obtained out upon the bench land between McKaye and Birch creeks, and also upon lands to the east. (*a*)

UNION COUNTY includes an irregularly shaped tract of land in northeastern Oregon, east of Blue mountains. The county comprises the head waters of Grande Ronde river and the western portion of its drainage basin. Its tributary, the Minam, and the lower course of the Grande Ronde form the eastern boundary of the county. On the south it extends over into the drainage basin of Powder river, and easterly along the south side of Powder River mountains to Snake river. It thus includes portions of two drainage systems, namely, the Grande Ronde, flowing toward the north into the state of Washington, and Powder river, flowing to the southeast into the Snake. Irrigation is not absolutely necessary, and the greater part of the crops is raised by dependence upon the rainfall. The bottom lands along the creeks are usually sufficiently moist, and are now cultivated, but on the higher lands bordering the valleys the soil is dry, and, although it is often of superior quality, is at present useless.

In the valley of Powder river, along the southern boundary of the county, and also along the tributaries which flow into this stream and into Snake river, the settlers have taken out small ditches to irrigate meadows, gardens, and fruit trees. The developments in some of the smaller valleys have already proceeded so far that all the available water supply is now utilized, and there are complaints from the older settlers that their prior rights are not respected and that other persons are depriving them of their share of water. In these smaller streams the amount of water diminishes rapidly after the early spring flood, and by July 1 there is barely enough for the needs of the land now under cultivation. In many cases water storage is already a necessity.

In Grande Ronde valley there is an ample water supply, and irrigation has been begun by using the waters of the smaller tributaries. The main river, especially in the northern part of its course, has cut itself a channel too deep to admit of water being taken out upon the valley lands. Among the hills are small patches irrigated from

---

[a] The amount of water in Umatilla river at Pendleton has been estimated by Mr. A. L. Adams, chief engineer of the Umatilla Irrigation Company. The following table gives by months or half months the maximum, minimum, and mean discharge as obtained by him:

ESTIMATED DISCHARGE OF THE UMATILLA RIVER AT PENDLETON, OREGON.

MONTHS.	Day.	Maximum.	Minimum.	Mean.
1891.				
February	1-28	320	140	180
March	1-15	2,250	140	386
Do	15-31	2,250	1,080	1,715
April	1-30	2,250	770	1,430
May	1-15	520	420	425
Do	15-31	520	140	391
June	1-15	180	140	150
Do	15-30	370	180	253
July	1-15	770	270	403
Do	15-31	580	60	200
August	1-31	60	60	60
September	1-30	55	35	45
October	1-31	65	35	50
November	1-30	580	60	172
December	1-31	520	410	510
1892.				
January	1-31	830	470	587
February	1-29	2,030	630	1,120
March	1-31	2,800	1,000	1,753
April	1-30	3,870	1,000	1,706
May	1-31	3,250	920	2,090
June	1-30	920	125	455
July	1-31	125	45	74

springs or from small streams, but as a general rule irrigation is not considered essential for anything except fruit trees. The Emele ditch takes water from Powder river, carrying it out upon the north side of the stream near the mouth of Big creek. It is 7 miles long, 4 feet wide, and cost $6,000. The water is diverted by means of a wooden dam placed permanently in the stream. There are 8 flumes, with an average length of 100 feet, along the ditch. The Farmer ditch takes water from Eagle creek, one of the tributaries of Powder river, carrying it out on the west side above the town of Newbridge. It is 4 miles long, about 4 feet wide, and has cost about $1,000. About 600 acres are irrigated, of which the principal part is in alfalfa. Fish Lake ditch heads in a small lake, the outlet of which has been partially closed in order to increase the storage capacity. From the lake the water flows in the ditch for about 2 miles across a divide, then follows for 4 miles down Fish creek, from which it is taken around another divide to Dry creek, down which it continues for 5 miles, and is recovered for a third time and brought around to Warm Spring valley. This was built by three men, and cost them about $1,200. Wheat, oats, alfalfa, clover, and potatoes are irrigated, about 200 acres of crops being raised in 1889.

WALLOWA COUNTY is in the northeastern corner of Oregon, being partially inclosed by Union county. It is bounded on the east by the Snake river and on the south by Powder River mountains, from which the streams flow in a general northerly course into the Snake or Grande Ronde river. The county as a whole is sparsely settled, and the surface is mountainous, or rough and broken. The principal industry is stock raising, large herds of cattle and sheep finding pasturage on the hill slopes and small plateaus. Tilling the soil is carried on in a small way near the towns and on the principal ranches, the main crop being for forage. In the valley bottoms irrigation is not always necessary, but upon the higher lands few crops can be raised without water. Rye, when sown in the fall or early spring, will grow and make a fair crop without irrigation, being ready to be cut for hay by the last of June, or completely matured during July. In 1888 and 1889 the crops were so nearly a failure that unusual attention was given to the consideration of better systems of irrigation, and in 1890 active work was begun on ditches taking water from the Wallowa river and from Sheep creek and other streams.

On the eastern side of the county is the Imnaha river, which flows northerly from the Powder River mountains for the greater part of its course parallel with the Snake, into which it finally empties. In the valleys along its tributaries, as, for example, on the Big, Little, and Middle Sheep creeks, are many places at which water can be diverted to advantage and a large amount of land brought under cultivation. Most of the ditches now in use are very short and cover a small acreage on each farm. There is an ample supply for all the land that can be irrigated from the main stream, but the greater portion of the arable land is at an elevation so great that only the smaller streams can be brought to it, and in these the volume decreases to an almost insignificant amount during the summer. The western side of the county is drained by Wallowa river, which flows into the Grande Ronde. At the head of this river is a large lake, which is apparently well adapted for water storage. By holding the spring floods in this lake a large area of land in the vicinity of Joseph and north of that point can be irrigated.

WASCO COUNTY is in northern Oregon, east of the Cascade range. On the north is the Columbia river, and on the west rises the great volcanic cone known as Mount Hood. The Deschutes river flows north through the county, in the lower portion of its course forming the boundary of Sherman county. The river receives the drainage from the eastern side of Mount Hood and the high mountain range stretching off toward the south. The water supply is large and well distributed over the western part of the county. There are valleys in this county possessing a rich alluvial soil. In summer the rainfall is often so small as to jeopardize the growth of fruit trees and of many of the crops. Generally, however, most of the cereals can be grown without irrigation, although with it the yield is from two to three times as great as it is without it. Corn is usually planted after summer fallowing, grows without irrigation, and is cut for fodder before it matures, the ground being sown to fall wheat without replowing. Potatoes on good ground and when well cultivated yield heavily without watering.

Irrigation has been practiced in a small way since the settlement of the county, but as it is not absolutely necessary developments have been slow, and there are no larger systems in operation. The principal irrigated areas are along Hood river and near Dalles. Besides these localities there are places scattered throughout the county at which small areas are irrigated by the waters of tributaries of Deschutes river or from springs. In the Hood River valley are a number of small ditches owned by individuals or associations of farmers, but their total capacity is far below the needs of the arable land. There is a demand for large canals to take water out upon both sides of the valley and cover large areas of land now unproductive. The farmers state that they are not able to build a comprehensive system without the aid of outside capital. The expense of clearing the land and bringing it under cultivation is very large, so that when the cost of irrigation is added to this the amount becomes too great for the means of the average settler.

The ditches in Hood River valley take water from the small tributaries, few, if any, making use of the abundant supply in the principal stream. As an example of these, may be cited one ditch 4 miles long, 2.5 feet wide, and which cost nearly $2,000. It receives water from springs on Mount Defiance and carries this out upon the west side of Hood River valley. The water supply is small, and only fruits and vegetables are irrigated. In the vicinity of Dalles are a number of small ditches, few of which are over a mile in length, and which, like the one above mentioned, are used almost entirely for gardens and other small areas of crops.

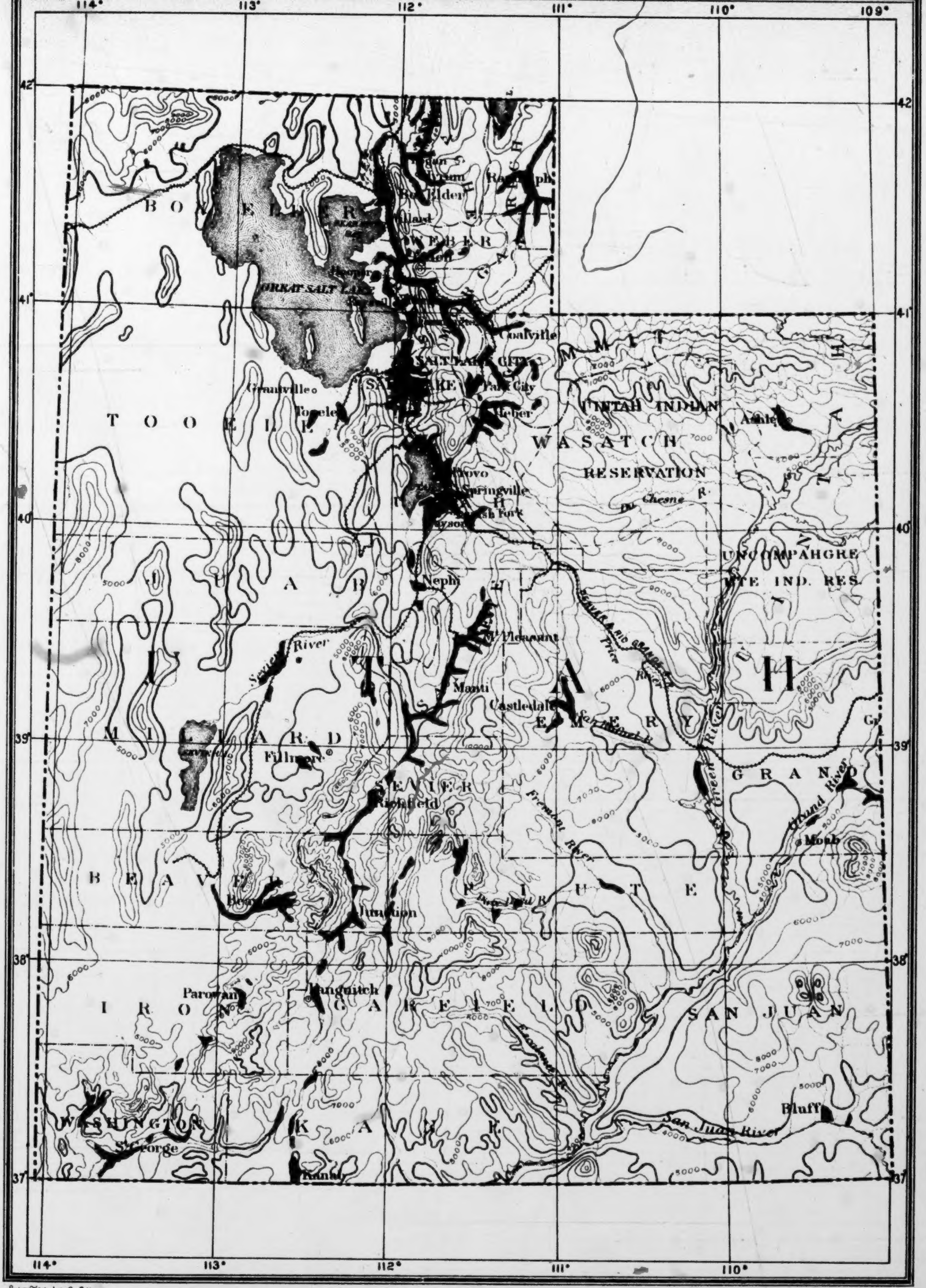
UTAH.

Total population (average per square mile, 2.53)		207,905
Number of owners of farms (5.06 per cent of population)		10,517
Number of irrigators (92.46 per cent of farm owners, 4.68 per cent of population)		9,724
Area of territory, land surface (82,190 square miles)	acres	52,601,600
Area irrigated in census year	do	263,473
Area of all farms, 41.42 per cent improved	do	1,323,705
Cereals raised in census year, including 15 acres in buckwheat and 3,389 acres in rye	do	122,878
Barley, average production, 25.36 bushels per acre	do	6,440
Corn, average production, 14.66 bushels per acre	do	5,782
Oats, average production, 26.29 bushels per acre	do	22,747
Wheat, average production, 17.93 bushels per acre	do	84,505
Alfalfa	do	88,152
Total value of all farms, including land, fences, and buildings		$28,402,780
Estimated total value of the farms irrigated in whole or in part		$22,198,000
Estimated value of all farm productions (sold, consumed, or on hand) for 1889		$4,891,460
Estimated value of productions, as above, from farms irrigated in whole or in part		$4,750,000
Average size of irrigated farms	acres	27
Average size of irrigated farms of 160 acres and upward	do	312
Per cent of acreage of irrigated farms of 160 acres and upward to total acreage irrigated		9.81
Average size of irrigated farms under 160 acres	acres	25
Average first cost of water right per acre		$10.55
Average annual cost of water per acre		$0.91
Average first cost per acre of preparation for cultivation		$14.85
Average value of irrigated land, including buildings, etc., in June, 1890, per acre		$84.25
Average annual value of products per acre in 1889		$18.03

GENERAL DESCRIPTION.

Utah stood next to California in the number of irrigators in the census year and was exceeded only by three states in the area of land irrigated. In size of farms, 27 acres, it stood at one extreme, while Nevada, with 192 acres, was at the other. This minute subdivision of the irrigated lands in itself testifies to a relatively large amount of care bestowed upon each area and implies that there should be a correspondingly large average value of products, as was the case, the average value, $18.03 per acre, being second only to that of California. It would have been first were it not that in California the average value of products was increased by the profits from the cultivation on a large scale of the highest class of fruit. In percentage of entire land surface irrigated Utah stood next to Colorado and California, and in percentage of total number of farms irrigated it was first, since a trifle over 90 per cent of all the farms of the territory were under irrigation to a greater or less extent. The relative proportion of the farm area irrigated, however, was somewhat small, coming below Arizona, Colorado, Idaho, and Montana, since only 22.03 per cent of the area of the farms was actually irrigated in the census year. The large irrigated farms, that is, those of 160 acres and over in size, formed less than 10 per cent of the total area irrigated, testifying again to the minute subdivision of agricultural lands. Deducting these, the average size of the small irrigated farms was only 25 acres. In first cost of water right Utah came next to California, while in average annual cost it stood sixth in the list.

Utah may be divided into two great divisions, distinct in topography and climate. The northern and western parts of the territory lie within the great interior basin of the continent, from which no water escapes except by evaporation, and the western and southern parts of the territory are in the drainage basin of the Colorado river, everywhere distinguished by lofty plateaus and deep canyons. The Wasatch range runs in a general north and south direction through the center of the northern half of the territory, wringing from the clouds the moisture which renders the counties along its western base so prosperous. The streams issuing from this great range, as a general rule, have cut through the mountains, and pour their waters toward the west, ultimately flowing into the Great Salt lake. This lake is but the remnant of a great body of fresh water which occupied all the principal valleys of western Utah, and from which came the rich sediments which render the broad bottom lands so fertile. Those valleys which are situated at the base of the mountains, although arid in climate, receive many streams, carrying a large part of the precipitation which has fallen upon the higher summits, and thus are most favorably


114°
113°
112°
111°
110°
109°
42°
41°
40°
39°
38°
37°
BOX ELDER
GREAT SALT LAKE
WEBER
Ogden
Brigham
Randolph
Coalville
SALT LAKE CITY
SALT LAKE
Park City
Heber
Grantsville
Tooele
TOOELE
WASATCH
UINTAH INDIAN RESERVATION
Ashley
Chesne R.
UINTAH
Provo
Springville
Spanish Fork
Payson
UNCOMPAHGRE UTE IND. RES.
Nephi
JUAB
Sevier River
Mt. Pleasant
Manti
Castledale
EMERY
Price River
UTAH
Green River
MILLARD
Fillmore
SEVIER
Richfield
GRAND
Grand River
Fremont River
Moab
BEAVER
Beaver
Junction
PIUTE
Parowan
Panguitch
IRON
GARFIELD
SAN JUAN
Escalante R.
WASHINGTON
St. George
KANE
Kanab
San Juan River
Bluff
5000
6000
7000
8000
10000

IRRIGATED ■

MAP OF UTAH SHOWING AREAS IRRIGATED IN 1889.

situated for cheap and effective irrigation. The valleys farther to the west, although equally fertile, do not receive streams as large or permanent, as the mountains bounding them are of less altitude, and therefore these enormous stretches of rich land, for the most part, must remain unproductive desert wastes, with only occasional patches or oases, where some small stream or spring, natural or artificial, is discovered.

The Colorado basin presents a great contrast to these conditions. Lofty plateaus, uplifted in great masses, have been deeply carved into canyons, the most stupendous in the world. On top of the plateaus the rainfall is light and irregular; the water quickly collects into rills, which soon seek a narrow gully, and then find their way into a canyon. In many localities, especially at rainy seasons of the year, grazing is good, and stock raisers have penetrated and taken possession of much of the country. Small towns have grown up in places where the canyons open out into valleys sufficiently wide to afford room for agriculture, and there the streams have been diverted upon the strips of fertile alluvial soil. These streams, however, flowing from a country of cliffs and naked rocks, are subject to sudden floods of great violence, since the rain of local storms does not soak into the ground, but rushes off at once, collects in the stream, and sweeps down with violence, carrying away dams, headworks, and even parts of canals.

Utah occupies the central position in the arid region, and therefore the details of irrigation in this territory possess more than ordinary interest, as they represent conditions intermediate between those of the north and south, the east and west. Besides, the irrigation methods and systems have been developed by men of English speaking origin, who, unaided by previous experience, have introduced methods of their own, and, taught by repeated failures, finally achieved success. Throughout the territory, excepting perhaps in the Colorado River drainage, there is more arable land than available water, and consequently the value of the land is dependent wholly upon the amount of water to which it is entitled, the most fertile areas without water being almost valueless. The point was long since reached when all the easily available water was appropriated, and the increase of cultivated area has been due to a more careful utilization of that supply.

PRIORITY OF RIGHTS AND DIVISION OF WATER.

Utah offers a striking contrast to the rest of the arid regions in the details of the customs of distribution of water according to priority of right, and also in the control of the water by the irrigators. Almost without exception the canals and systems of ditches have been built by farmers and are controlled by them in every minute detail. An apparent exception is in the case of the municipalities or chartered cities which have built and now own systems of irrigation, but this exception is only apparent as these cities, so called, are controlled by the farmers, so that the water is administered by officers representative of the irrigators as a class. The municipalities, however, have a certain advantage over farmers' associations, in that they can levy taxes for the use of water and collect them through the ordinary machinery of such organizations.

In nearly every valley of Utah there is now more land under cultivation than is supplied with water to mature the crops in all years. The first settlers in these valleys, finding that there was more land than could be cultivated by themselves, encouraged other farmers to come in, and gradually cultivation extended, until at last a time came when the water would not serve all the land under cultivation. The principle was early established that those farmers who first made use of the water should ever afterward be entitled to sufficient water to irrigate the amount of land originally cultivated by them, and that the later comers, whenever scarcity occurred, should not take the water until those enjoying prior rights had satisfied their needs, the latest comer being the first to be deprived, and those settling before him losing their water supply in succession as it became less and less.

For convenience, however, the rights are not held in the exact order of settlement, but are divided into classes, all the individuals of one class or group sharing the water according to their respective claims. For example, all older settlers who used water for a certain acreage before some arbitrarily fixed date are considered as having prior rights; those who cultivated other lands at a later time are considered as having rights secondary to these, and those who cultivated lands during a still later period have third rights, and so on. The farmers owning first rights are entitled to the use of the water to the amount originally appropriated until their needs are satisfied; those owning the second rights can enjoy the use of the surplus water after the prior rights have been supplied, while those owning third rights are by law only allowed to use such water as the farmers having first and secondary rights can not use or claim. A farmer having prior rights may also have secondary rights, and even third rights, to the water for lands not covered by his first rights, and thus in times of scarcity he does not lose all his water, but is able to mature a small portion of his crop. The man, however, who has last rights only can not be sure of success, and unless the snowfall in the mountains is heavy during the winter he may not dare to plant in the spring, knowing that he can not secure water later in the season.

Those irrigators who own prior rights to the water practically enjoy a monopoly of it, for with the advance of settlement everywhere in the territory and the bringing under cultivation of more land than can be readily watered lack of supply becomes chronic among later irrigators. This monoply, although often regarded as a great injustice by these later comers, is unquestionably essential to the success of irrigation, for were all irrigators required each year to divide the water among all who might demand it, in a short time there would not be enough distributed to any one man, and suffering would ensue among all, instead of among those who may be considered the excess of population. This principle of monopoly of water by a certain few of the farmers is recognized not only by custom but even by law throughout the arid lands, and the claimants possessing this monopoly can alone be sure of maturing their crops. These primary rights, however, are not always clearly defined or carefully guarded. There is a tendency among the owners of first rights to claim more water than was originally appropriated by them, and on the other hand, the irrigators having second and third rights encroach upon the supply claimed by the owners of prior rights. Those having the second or last rights do not always tamely submit on seeing their crops parch and wither and their trees die for lack of water while their neighbors are enjoying an ample supply, and quarrels are constantly arising. The attempt to farm without a prior right to water is by some declared to be a curse, and demands are made for a more just and equitable division.

With the present unregulated water supply the success of farming depends largely upon the amount of snowfall in the mountains and the time of year in which this occurs. If the snow falls early in the winter it usually becomes hard, and does not melt until the heat of summer has become intense and the needs of the crops are greatest. On the other hand, if the snow falls late in the winter, it does not have time to become compact, but melts in the early spring, and runs to waste long before the farmers have the greatest necessity for it. A number of attempts have been made in various parts of the territory to regulate the supply, and storage works have been built on a small scale, some of which are successful. These, when placed in suitable localities out of the reach of floods, not in the course of a river or the drainage from a large area of barren rocks, have justified the plans of their builders, and have rendered possible the cultivation of numerous tracts of valuable lands.

The person at the lower end of a long ditch, or taking water from a ditch far down the course of a stream after it leaves the canyon, is always at a disadvantage in the summer, for if his proportion is allotted at the point where others take their water, this amount is usually lost in traversing the distance to his fields. It often happens in summer that if water is allowed to flow by the head gates of one canal company for the purpose of supplying a ditch below, the whole amount is evaporated or lost in the channel before reaching the lower ditch, and neither party is benefited. After the water is taken into the main canal there is often considerable loss in the height of the irrigating season, due to the weeds, which grow luxuriantly in the water wherever the current is sluggish, and may completely choke the channel if not cleaned out. Sometimes these are pulled up by rakes or mowed under water. In a few cases it has been found necessary to turn the water out of the canal entirely, even when crops were almost in danger, in order to allow the aquatic plants to dry and be killed by the sun. Another source of annoyance and expense is found in the burrowing habit of gophers or moles. These little creatures dig into the banks of ditches or into earth dams and often cause leaks, resulting in the sudden washing away of portions of these structures.

Owing to the difficulties and uncertainties concerning the supply and distribution of water, many farmers in the northern counties have declared that dry farming is preferable wherever it is possible, and that in many localities, by carefully preparing the land by summer fallowing and planting at a proper season, cereals can be raised to greater advantage than by irrigation, although the yield per acre is far less. Alfalfa, or, as it is usually termed, lucern, is raised in many counties without water, one cutting of the plant being made, and then, no water being applied, a crop of seed is raised. The number of cuttings of alfalfa, the crop which varies most with the season, depends directly upon the water supply. If the supply is ample throughout the season three cuttings are obtained, but when water is scarce, it is used upon the grain, vegetables, and trees, and the alfalfa is generally allowed to run to seed.

WELLS.

The flowing wells throughout Utah have great similarity in character, since they are found in localities whose topography and general surroundings have many points of resemblance. The successful wells are confined to the low grounds of valleys composed of unconsolidated lake beds, and are usually below the level of lands irrigated for many years. Beginning in the northern part of the territory, small flowing wells are found in the lower part of Cache valley, in Cache county, and along the Malade valley, in Boxelder county. From this locality southerly large numbers are to be found along the eastern shore of Great Salt lake, especially near Ogden, in the western end of Weber county, also in Davis county and on the low grounds of Salt Lake county. The line of wells continues, with occasional breaks, along the southeastern shore of Great Salt lake and down into Tooele county, in the neighborhood of Grantsville and the town of Tooele.

Passing southward, into Utah county, similar flowing wells are found in great numbers on the northern, eastern, and southern shores of Utah lake, and still farther south, in Juab county, near Nephi. In the drainage basin of the Sevier river, wells almost identical to those of the valleys farther north are in use in the Sanpitch valley, in Sanpete county, also on the low grounds of Sevier county and far down the river on the Sevier desert, near the towns of Oasis and Deseret, in Millard county.

In all these localities the tubing or casing of the well passes through alternations of clay, sands, and gravel, the two last named layers being usually filled with water, which, from the basin-like structure of the beds, is under pressure sufficient to bring it to or above the surface of the center of the valley. These sands and gravels approach or reach the surface near the edge of the valleys, and there receive water either from rainfall or from the streams flowing from the mountain slopes.

Such a well consists of a pipe of from 1.25 to 4 inches in diameter forceddown to or into the water-bearing strata to depths usually of from 100 to 150 feet, the lower end of the pipe being perforated or having suitable devices for admitting the water. This is usually clear, cool, and palatable, suitable for the ordinary purposes of household supply. It, however, often contains a notable amount of mineral matter, and is occasionally even salty. Most of the wells have been put down by farmers near their houses or barns, and the excess of water is conducted away to the shade trees or to kitchen gardens. Comparatively few of the wells are used for irrigation in the broad sense, that is, for field crops, but the great majority of those not near houses are in pastures, or meadows occasionally used for pasturage.

In putting down the wells there have been comparatively few failures to obtain flowing water, for the farmers have learned to keep within the bottom lands inside the defined artesian area. The increase in number of wells, however, has begun to result injuriously in many cases, and a large number of wells are reported to have decreased materially. In the various basins all stages in the history of artesian exploitation can be found. For example, in some of the larger basins the wells, comparatively few in number, show no signs of diminution in flow; in others the quantity discharged from some of the older wells has decreased by one-half or one-quarter, and again in other basins many of the wells barely flow, fluctuating with the changes of the season. Deep drilling, namely, beyond 400 or 500 feet, so far as has been ascertained, has been unsuccessful in obtaining fresh water. With increased depth the water is liable to be brackish or even heavily charged with saline matters. In some of the wells along the eastern shore of Salt lake inflammable gas has been found, and a small amount of petroleum has been reported.

VALUE OF PRODUCTS.

The variation in the average value of products per acre for each county, as shown in the following table, is due somewhat to the character of the crop, but more to the state of cultivation and the water supply, and to some extent to the location of the land with regard to markets. In the northern end of the territory, as, for example, in Rich county, the average value of products is low, since forage crops are raised principally, and, the altitude being great and the water supply somewhat limited, the average yield is small. The average size of the farms also is large, showing that cultivation is carried on in a broad way, and that the greater part of the irrigation is for crops which require but little care.

In the counties lying along the base of the Wasatch mountains, near the markets of the cities of Salt Lake, Ogden, and Provo, and other centers of population, the farms are small and highly cultivated, and, as a consequence, the value of products is large, the counties on either side showing as a rule a lower average value. An exception to this is found in the case of the counties on the Colorado drainage, where the water supply is scanty and the cost of irrigation is at a maximum, for here (as, for instance, in the case of Washington county) the expense of bringing water to the land is so great that the farms are very small and the products per acre large. The semitropical character of the fruit and other crops in this great drainage basin also tends to give a greater value to these averages.

CONDITION OF IRRIGATION IN EACH COUNTY.

NUMBER OF IRRIGATORS, AREA IRRIGATED, FARMS, AND CROPS IN EACH COUNTY IN UTAH IN 1889.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.	OWNERS OF FARMS. (a)		IRRIGATORS.		Area of counties in acres.	FARM AREA.		Cereals. (Acres.)	Alfalfa. (Acres.)	AREA IRRIGATED.			Average value of products per acre.
				Total number.	Per cent of population.	Per cent of farm owners.	Per cent of population.		Acres.	Per cent improved.			Per cent of area of county.	Per cent of total farm area.	Per cent of land owned by irrigators.	
Total	9,724	263,473	27	10,517	5.06	92.46	4.68	52,601,600	1,323,705	41.42	122,878	88,152	0.50	19.90	22.03	$18.03
Beaver	200	7,682	38	210	6.29	95.24	5.99	1,730,560	16,165	57.28	2,224	1,106	0.44	47.52	58.40	9.92
Boxelder	359	10,472	29	478	6.25	75.10	4.70	4,490,240	430,383	13.68	10,932	3,784	0.23	2.43	2.57	15.25
Cache	908	30,923	34	1,065	6.87	85.26	5.85	697,600	100,106	55.28	24,549	4,077	4.43	30.89	34.13	14.30
Davis	585	12,866	22	682	10.10	85.78	8.67	185,600	81,968	50.55	13,363	9,664	6.93	15.70	25.22	32.93
Emery	264	7,344	28	266	5.24	99.25	5.20	3,662,720	29,611	45.07	3,375	3,110	0.20	24.80	25.47	17.01
Garfield	82	2,234	27	93	3.79	88.17	3.34	872,960	7,161	62.23	1,172	485	0.26	31.20	38.99	11.64
Grand	56	1,139	20	56	10.35	100.00	10.35	2,032,000	6,055	82.54	411	381	0.06	18.81	18.81	19.05
Iron	193	3,539	18	198	7.38	97.47	7.19	2,199,040	5,689	88.22	2,394	1,218	0.16	62.21	62.97	14.94
Juab	85	1,946	23	97	1.74	87.63	1.52	2,449,920	15,206	45.46	241	597	0.08	12.80	14.30	11.66
Kane	107	1,798	17	120	7.12	89.17	6.35	2,670,080	7,861	45.97	848	528	0.07	22.87	27.84	21.81

a Includes owned and hired farms, assuming one farmer to each.

NUMBER OF IRRIGATORS, AREA IRRIGATED, ETC., IN EACH COUNTY IN UTAH IN 1889—Continued.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.	OWNERS OF FARMS.		IRRIGATORS.		Area of counties in acres.	FARM AREA.		Cereals. (Acres.)	Alfalfa. (Acres.)	AREA IRRIGATED.			Average value of products per acre.
				Total number.	Per cent of population.	Per cent of farm owners.	Per cent of population.		Acres.	Per cent improved.			Per cent of area of county.	Per cent of total farm area.	Per cent of land owned by irrigators.	
Millard	304	8,199	27	306	7.59	99.35	7.54	4,295,680	41,438	35.49	2,326	3,452	0.19	19.79	21.89	$14.58
Morgan	233	5,298	23	238	13.37	97.90	13.09	464,000	20,324	41.43	2,616	2,491	1.14	26.07	20.68	18.16
Piute	143	5,299	37	143	5.03	100.00	5.03	2,304,800	18,081	57.46	2,261	628	0.22	29.31	29.31	11.08
Rich	184	17,268	94	193	12.64	95.34	12.05	627,200	94,672	30.76	1,532	1,783	2.75	18.24	18.57	9.00
Salt Lake	1,264	25,392	20	1,366	2.34	92.53	2.16	501,760	73,271	65.44	6,962	12,928	5.06	34.65	40.96	28.73
San Juan	38	777	20	38	10.41	100.00	10.41	5,873,920	4,097	38.71	386	149	0.01	18.97	18.97	27.95
Sanpete	1,155	30,938	27	1,191	9.06	96.98	8.79	1,141,760	95,364	63.86	12,913	5,939	2.71	32.44	32.93	15.18
Sevier	311	11,547	37	312	5.03	99.68	5.02	1,198,080	27,579	66.61	6,075	2,423	0.96	41.87	41.87	11.53
Summit	276	10,140	37	362	4.68	76.24	3.57	1,959,680	34,186	52.21	1,551	2,109	0.52	28.98	37.85	15.03
Tooele	267	5,766	22	301	8.14	88.70	7.22	3,993,600	41,236	43.61	1,769	2,066	0.14	13.98	16.38	14.46
Uinta	186	7,611	41	186	6.73	100.00	6.73	3,733,760	19,789	67.65	3,579	2,688	0.20	38.46	38.46	10.61
Utah	1,161	25,236	22	1,198	5.04	96.91	4.88	1,271,040	68,637	74.05	8,500	13,583	1.99	36.77	38.58	22.50
Wasatch	259	6,475	25	289	8.04	89.62	7.20	2,204,160	19,796	68.85	2,718	1,723	0.29	32.71	38.67	10.22
Washington	176	2,251	13	187	4.66	94.12	4.39	1,565,440	4,872	74.59	1,225	1,196	0.14	46.20	48.84	32.19
Weber	928	21,335	23	942	4.15	98.51	4.08	416,000	59,358	65.45	8,946	10,044	5.13	35.94	36.07	22.72

BEAVER COUNTY is on the western side of Utah, adjoining Nevada, and a little south of the center of the territory. It extends from the summits of the Tushar mountains westward into the desert region south and west of Sevier lake, or sink. The agricultural land is at the eastern end of the county, principally in the valley between the Tushar and the Mineral mountains, along Beaver creek and its tributaries, the principal towns being Beaver, Greenville, and Adamsville. A fourth town, Minersville, is situated lower on the creek, at the foot of the Mineral mountains, where Beaver creek leaves the foothills and enters upon the desert region. The average altitude of the agricultural land is about 6,000 feet. Alfalfa and the small grains are the principal crops, and in some localities there are a few orchards. The water supply of the early spring is ample for all the crops now under cultivation, but it becomes scanty during the latter part of May, and in July many of the crops which have not matured are lost.

Water storage has been attempted in a number of cases, but with little success, owing to lack of skill and care in constructing reservoir embankments. Many of the dams have been swept away during times of high water, resulting in great loss and discouragement. The experiments which have been made, however, lead the farmers to believe that with proper engineering supervision reservoirs can be made to hold ample water, not only for their present needs, but also to bring under cultivation a large amount of now useless lands. The only streams of importance in the county are Beaver creek and its tributaries, Indian, and North creeks. Various small canals lead from these creeks, and the waters are entirely appropriated in times of scarcity, only the irrigators near the head waters being able to obtain sufficient water for their needs.

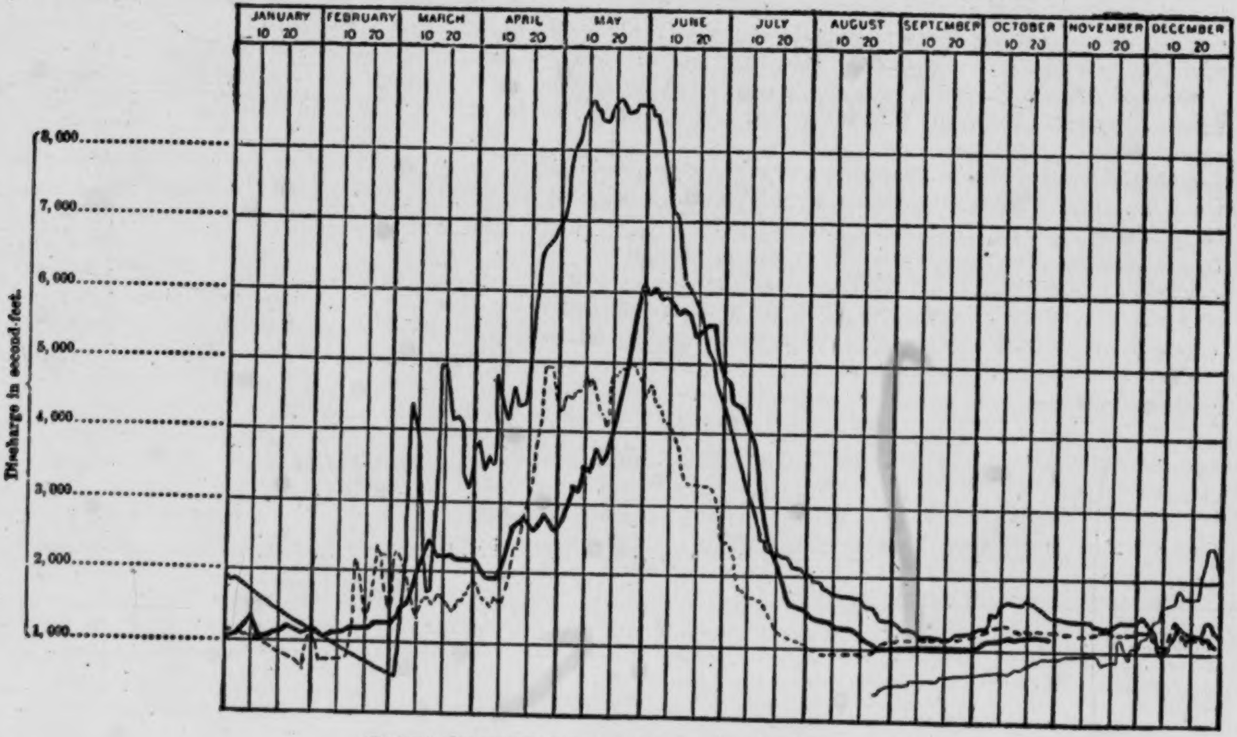
BOXELDER COUNTY is in the northwestern corner of Utah, and includes the greater portion of Great Salt lake. The land north and west of the lake is for the most part level, much of it being a sandy desert, but the eastern border of the county extends to the summit of the Wasatch range, and is thus comparatively well watered. The principal body of cultivated land is along the foot of the Wasatch mountains and in the Malade valley. There is also some tilled land on the extreme western edge of the county along Grouse creek. Not all of the land under cultivation is irrigated, but there is a considerable acreage of dry farming in the long strip of land at the foot of Wasatch mountains, extending northward into the Malade valley. In the vicinity of Mantua, Honeyville, Deweyville, and Portage crops of wheat, oats, corn, rye, potatoes, and alfalfa, as well as fruit trees, are successfully raised. The yield is not as great as on the irrigated land, the amount being given as from one-third to one-half the product of land under irrigation. When alfalfa is raised in this manner, one cutting is made in July and the second crop is allowed to go to seed. Farmers attribute their success in dry farming to two causes: first, the nature of the soil, which retains its moisture for a long time, and, second, many small springs issue from the mountains and slowly percolating through the soil keep it moist.

Water storage in a small way has been tried to a considerable extent in this county. Small earthen dams have been built to retain a portion of the surplus spring flood, and the water has been used successfully. The irrigators state that this system has proved to be practicable, and that with greater care and skill large areas can be brought under cultivation. The unregulated water supply is ample for all needs until about the latter part of June. About the first of July it begins to diminish, and crops are often lost after that time. The present water supply of this county is derived from the various small streams which issue from the canyons. These being distributed along the mountains, there has been no necessity for large canals, but a great number of small ditches have been built. These are owned either by individuals or by the towns to which they bring water. In addition to the small streams there are two rivers of considerable size, the Bear and Malade. Both of these rivers flow at

VIEW IN CANYON OF BEAR RIVER, BOXELDER COUNTY, UTAH, LOOKING EAST, SHOWING WASTE WAYS OF BEAR RIVER CANAL ON THE LEFT a depth of from 50 to 100 feet or more below the general level of the agricultural land, having cut their channels deep into the plain, once the bed of Salt lake. The waters of the Malade are impregnated with saline matter and are not suitable for irrigation.

Bear river enters the county by a narrow, rocky walled canyon, through which it passes with rapid descent. At the head of this canyon a low dam has been built to divert the waters into two canals, one on each side of the river. These canals are to pass through the canyon in tunnels or galleries in the rocky walls and then enter upon the fertile plains surrounding Great Salt lake. The accompanying illustration shows the general character of this canyon and of the tunnels by which the water is diverted. The canal on the west side of the river is nearly completed, but that on the east, leading southward toward the city of Ogden, is reported to have been temporarily abandoned. This great project, when completed, will be the largest of the kind in Utah, and will bring under cultivation thousands of acres of fertile land now useless or but poorly cultivated. The quantity of water in this stream has been measured at the lower end of the canyon and about a mile below the dam just mentioned. (a)

DIAGRAM OF DAILY DISCHARGE OF BEAR RIVER AT COLLINSTON, BOXELDER COUNTY, UTAH.



DISCHARGE OF BEAR RIVER AT COLLINSTON, UTAH.

(Drainage area, 6,000 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
June	....	....	*800	47,600	0.15	0.13
July 24 to 31	385	340	362	22,263	0.07	0.06
August	450	385	417	25,645	0.08	0.07
September	610	450	500	30,285	0.09	0.08
October	825	610	728	44,772	0.14	0.12
November	1,000	780	848	50,456	0.16	0.14
December	1,925	955	1,395	85,792	0.27	0.23

* Estimated.

---

a In the diagram the discharge for 1890 is indicated by the lighter continuous line, that for 1891 by the broken line, and that for 1892 by the heavier continuous line. The fluctuations at this point are best shown by the accompanying table.

CACHE COUNTY is in the northern part of the territory and includes the greater portion of the valley of the same name. The northern end of this valley is in Idaho, and thus the agricultural land and the water supply are divided between two great political divisions, giving rise to complications regarding water rights. Bear river flows southward into this county and then turns abruptly to the west, passing through a canyon into Boxelder county, as already described. This river flows at a considerable depth below the general level of the agricultural land and accordingly it has been found too expensive to bring the water out upon the lands of this valley. Various tributaries, however, come from the high mountains to the east, and it is upon the waters of these streams that the greater part of the agricultural operations depend.

The general elevation of the land under cultivation is about 5,000 feet, and the climate is highly favorable for wheat, oats, rye, and other small grains. The irrigated land is principally along the edges of the valley, extending up on the bench land or beaches left by the retreating waters of the lake, which once occupied this arm of the great basin. In the center of the valley and at other points where water is not available dry farming is being tried on a somewhat extensive scale. Wheat, rye, oats, corn, and potatoes are being raised by careful tilling, the product per acre being from one-half to one-third that on irrigated land. It is reported that from 12 to 15 bushels of wheat and from 10 to 12 bushels of rye to the acre is a fair crop. Fall wheat is extensively raised. To compensate for the smaller yield per acre larger tracts are farmed, and it is even claimed by some farmers that the average profits are greater, since the expense of the water is avoided and larger tracts are cultivated at less cost per bushel of wheat raised than is the case with the irrigated grain. This is notably the case in many seasons when the rainfall happens to be favorable. The use of water on the gravel bench lands surrounding the valley has caused some of the lower lands to be saturated by seepage, so that crops can be raised and even meadows formed. In some instances this saturation has proceeded so far that a system of drainage must be put in operation.

On the western side of the valley the water supply is far more scanty, on account of the lower altitude of the mountain range. Storage reservoirs have been attempted here and a few are in successful operation. At Newton there is a reservoir utilizing the surplus waters of Clarkston creek, and it is reported that 1,000 acres are cultivated by that means. The inhabitants of the towns on this side of the valley are preparing to increase the storage capacity by enlarging the old reservoirs and building new ones. Although agriculture in this county is in such a prosperous condition, there remain enormous tracts of good land, especially on the west side of the valley, still unproductive or from which only an occasional crop is obtained. It is known to be feasible to bring the waters of Bear river out upon this land, the engineering obstacles being by no means insuperable. There is a question,

DISCHARGE OF BEAR RIVER AT COLLINSTON, UTAH—Continued.

MONTHS.	Discharge in second-feet.			Total for month in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1890.						
January	....	....	*1,500	92,250	0.29	0.25
February	....	....	*1,000	55,500	0.17	0.17
March 2 to 31	4,860	1,100	3,188	196,062	0.61	0.53
April	6,680	3,600	4,953	294,703	0.92	0.83
May	8,220	6,890	7,924	487,326	1.52	1.33
June	7,940	4,440	6,234	370,923	1.16	1.04
July	4,230	2,060	3,250	199,875	0.62	0.54
August	2,060	1,545	1,754	107,871	0.34	0.29
September	1,425	1,310	1,344	79,968	0.25	0.22
October	1,665	1,365	1,544	94,956	0.30	0.26
November	1,425	1,365	1,403	83,478	0.26	0.23
December	1,545	1,000	1,243	76,444	0.24	0.20
Per annum	8,220	1,000	2,945	2,130,356	6.68	0.49
1891.						
January	....	....	*1,000	61,500	0.19	0.17
February	2,200	825	1,308	72,594	0.23	0.22
March	2,340	1,425	1,768	108,710	0.34	0.29
April 1 to 11	5,000	1,665	2,729	162,375	0.51	0.45
May	5,000	4,020	4,569	280,963	0.88	0.78
June	4,720	2,480	3,595	213,902	0.67	0.60
July	2,270	1,100	1,565	96,063	0.30	0.26
August	1,100	825	938	57,687	0.18	0.16
September	1,200	825	986	58,667	0.18	0.16
October	1,310	1,200	1,235	75,952	0.24	0.21
November	1,310	1,200	1,262	75,080	0.24	0.21
December	1,545	1,100	1,216	74,784	0.23	0.20
Per annum	5,000	825	1,845	1,338,310	4.19	0.31
1892.						
January	1,545	1,000	1,202	73,923	0.23	0.20
February	1,310	1,000	1,209	69,517	0.22	0.20
March	2,480	1,310	2,037	125,275	0.39	0.34
April	2,760	1,925	2,397	142,621	0.45	0.40
May	6,260	2,480	3,869	237,943	0.74	0.64
June	6,260	4,790	5,660	336,770	1.05	0.94
July	4,650	1,545	3,037	186,775	0.58	0.51
August	1,545	1,000	1,195	73,492	0.23	0.20
September	1,000	1,000	1,000	59,500	0.19	0.17
October	1,200	1,000	1,131	69,556	0.22	0.19
November	1,310	1,100	1,195	71,102	0.22	0.20
December	1,425	1,100	1,235	75,952	0.24	0.21
Per annum	6,260	1,000	2,097	1,522,426	4.76	0.35

*Estimated.

however, as to the practicability of so doing, both on account of the limited amount of water that can be relied upon at all times and on account of the complications arising from the peculiar position of Bear river, crossing, as it does, from one state into another. By a proper regulation of Bear lake and the waters of Bear river the success of any such enterprise could be assured.

On the eastern side of the valley are important streams draining the high mountains. On the north is Cub river and its tributaries, and at about the center of the county is Logan river, at the mouth of whose canyon is located the city of Logan. A number of irrigation works take water from these rivers, the most important of these being the Hyde Park and Smithfield canal, the Logan and Richmond, Logan and Hyde Park, and Logan and Benson; these carrying water northerly in a general parallel course along the bench lands. A few measurements were made of the discharge of Logan river at points above the high line canal. On August 14, 1889, the discharge was 126 second-feet; on August 17, 128 second-feet, and on August 24, 106 second-feet. The Logan, Hyde Park and Smithfield canal on June 12, 1889, was carrying 39 second-feet and the Logan and Richmond canal 68 second-feet. On June 14 the Logan and Hyde Park canal was carrying 35 second-feet and the Logan and Benson canal 38 second feet. Besides these there are a number of canals irrigating lands in the south end of the valley near Paradise, Hyrum, and Wellsville. Wherever water can be brought upon the bench lands the farmers are usually successful in producing large crops and in raising fruits of unusual excellence, the conditions being apparently more favorable than on the lower grounds.

Davis county lies between the Wasatch mountains and the shores of Great Salt lake, and extends from the canyon of Weber river on the north nearly to Salt Lake city. The agricultural land is thus in a long and comparatively narrow tract. The larger part is in the nearly level bottom of the ancient lake, but a portion extends up to the benches or old shores of the lake. The water supply is comparatively large, on account of the peculiar topography of the county. On the east are the lofty peaks of the Wasatch. The winds striking against them are deprived of their moisture in the form of rain or snow. Innumerable small streams issue from the mountains, and springs appear along the base. The water from these, if not used or evaporated, saturates the ground at the base of the mountains, and thus the little streams gradually disappear into the soil, whence the water is either slowly evaporated or ultimately finds its way into Great Salt lake. A small quantity of this water is recovered by flowing wells, the pipes for which are driven in the lower bottom lands. The supply thus obtained is of great value for domestic purposes, for watering stock, and for the irrigation of small patches of garden, as well as of fruit and shade trees. Many of the owners of these wells report that the water is slightly brackish and not always suitable for irrigation purposes.

One noteworthy feature of water conservation in this county is the development of springs by tunnels driven into the flanks of the mountain range. These tunnels are driven on a slightly ascending grade in the same manner as an ordinary mine or prospect tunnel, and after penetrating loose material and decomposed rock they usually reach the comparatively impervious strata. Here the course is often turned or lateral tunnels are driven along the solid or bed rock parallel with the surface. By means of these tunnels the small amount of moisture seeping through the beds on the lower slope is caught and conducted to the surface, where it can be used for domestic supply and irrigation.

The lower lands of the county are to a certain extent wet by the seepage from the springs and irrigation carried on above, so that large areas of wheat and barley are raised without artificial application of water. Wheat is usually sown in September and October, the land being prepared by summer fallowing, and it yields from 10 to 20 bushels per acre, and barley from 15 to 25 bushels per acre, the amount depending largely upon the winter rainfall. Farmers report that probably twice as much could be raised on the same land by irrigation, but taking all things into consideration the returns are probably greater than by using water, because of the smaller first cost of cultivation. On these lower lands the water must be carefully applied in order to avoid bringing the alkaline salts to the surface and thus ruining the land. Drainage is in many cases necessary, and it is probable that with the progress of irrigation large works of this kind will be required. Besides wheat and barley, one crop of alfalfa is raised without water, and in many instances it is stated that considerable acreages of this forage plant have been started from the seed and cropped regularly without irrigation. It is impossible, however, to raise vegetables or trees without a sufficient water supply.

The water supply being distributed along the base of the mountains, there are consequently many ditches, few of them, however, being of noteworthy size. The land under cultivation exceeds the ordinary supply of these ditches, and a loss of crops is the result. Considerable care, however, is taken in the management of the available water, and during the latter part of the season lands are irrigated both day and night, the water being in continual use by one irrigator or another. The farmers often complain that their lot is indeed hard when they are compelled to take water at any time of the night, and often to work all night in order to apply it to crops to the best advantage. The irrigators owning secondary rights to the water generally begin to irrigate in March and continue until about the middle of June, when the supply, usually ample to June 1, becomes so scanty that those owning primary rights demand the full stream in order to mature their late crops and water their orchards and gardens.

Thus a large number of the farmers do not venture to plant fruit and shade trees to an extent greater than can be watered by hand, because of the uncertainty of obtaining the necessary supply from the ditches during the summer. Water storage and conservation, although practiced to a very small extent in this county, are earnestly desired by most of the irrigators on account of the many difficulties and uncertainties which they encounter in spite of the comparatively good water supply. There have been a number of long and expensive legal controversies, and the water of their largest canal has been cut off for a time by order of court.

EMERY COUNTY is east of the center of the territory and lies wholly within the drainage of Green river, one of the forks of the Colorado. The county is composed principally of great plateaus, which descend rapidly to the east and south by steep escarpments. Through these plateaus deep canyons have been cut by the Price, San Rafael, and Fremont rivers and their tributaries, and also by the smaller streams flowing into Green river. On the plateaus and along the cliffs there is little vegetation, and whenever heavy storms occur enormous quantities of earth are loosened and washed down the narrow canyons, causing floods of great violence and destructiveness. Mud, sand, and bowlders are rolled along in these torrents, and the canyons are carved still deeper by this mass of turbulent material. Agricultural land is scattered along the streams in occasional narrow valleys wherever the canyons open, and also on the plateaus near the head waters of the streams before these have entered the deep canyons. The elevation of the tilled land varies from 4,000 feet along Green river to 6,000 feet or upward in the western part of the county. The water supply is derived from the streams just mentioned and is taken out upon the land by ditches made by the farmers, no crops being raised without irrigation. Along Green river small bodies of land are irrigated by means of norias or undershot water wheels, carrying buckets upon their rims.

The expense and labor involved in maintaining the irrigating ditches is large on account of the changeable character of the streams, which are liable at any moment to become raging torrents, carrying away head works or portions of canals, or even overwhelming the agricultural lands themselves. These floods often subside as rapidly as they come, and leave the channel almost, if not quite, dry. The principal towns are in the western part of the county, not far from the head waters of the streams, since at this place the water is more easily controlled and can be taken out upon the fields. The irrigators state that in order to bring all their land under cultivation it will be necessary to store a portion of the flood waters by diverting them from the streams into suitable depressions or into reservoirs, the facilities for whose safe construction are excellent.

GARFIELD COUNTY is in the southern part of Utah, extending in a narrow belt from the Colorado river westerly across the head waters of the Sevier. The county is thus composed for the most part of high plateaus and mountain ranges deeply cut by canyons, which rarely open to a sufficient width for agricultural operations. Sheep and cattle raising is the principal industry, the soil being tilled in the vicinity of home ranches of the herders or of the small towns from which supplies are obtained. There are a few broad valleys in the western part of the county, high among the mountains, where meadows are found or are made by turning the streams out upon the bottom lands.

The tilled land is along the head waters of the east and the west fork of the Sevier, and also to a less extent near the sources of the Paria and Escalante rivers, both flowing into the Colorado. The water supply is in general ample for all purposes, but when it is used freely from the streams flowing into the Sevier, farmers living in the valleys farther down stream suffer for lack of it. The peculiar manner in which the counties are divided in this portion of Utah stands in the way of water conservation, since it is difficult to enforce economy along the river, flowing, as it does, across several counties.

GRAND COUNTY was formed of that portion of Emery county between the Colorado line on the east and Green river on the west. The principal agricultural land is on the east side of Grand river, northwest of La Sal mountains, at an elevation of about 4,000 feet. The valleys, surrounded by high plateaus or mountains and thus protected from violent winds, have an almost semitropical climate. The water supply is derived from small streams, which issue from La Sal mountains in quantities more than sufficient for present needs, for agricultural resources have not been developed up to the easily available water supply.

The principal settlements are at Moab, at the mouth of the Spanish valley, and in the Colorado valley, about 6 miles below the mouth of the Dolores river. As yet injurious insects and parasitic growths destructive to plant life have not invaded these isolated valleys, and farmers have been unusually successful in their attempts to raise fruits and grain. The tilled land is along the small streams, the topography being such that canals or large ditches have not been found necessary, the water being taken directly from the streams by short laterals to the fields. There are immense tracts of fertile land along Grand river awaiting the construction of suitable canals, and it is only a question of time when large areas now devoted to grazing will be brought under close cultivation.

IRON COUNTY is in the southwestern part of the territory, below Beaver county, to which it is similar in many respects. The tilled land is confined to the eastern end of the county, and lies in narrow valleys at an elevation of about 6,000 feet along the foot of the mountains or escarpments which bound the great plateaus of southern

Utah. The water supply is derived from the small streams which issue from these high table lands, the amount depending upon the depth of snow falling upon the high lands during the winter. These streams are subject to violent floods in the spring, and as a rule decrease in June, furnishing barely enough water for the land then under cultivation.

The county contains immense tracts of barren land, the soil of which is fertile and produces good crops where water is applied. The acreage now under cultivation is relatively very small, but it is as large as the present unregulated supply will permit. The farmers, like those of Beaver county, are convinced of the necessity and feasibility of storing the flood waters in order to bring larger areas under cultivation. The greater part of the flood water is now unused, although as much as possible is diverted upon the hay lands in order to saturate them, and thus produce some grass for grazing. In the fall, also, after the crops are matured, any water remaining in the streams is thus utilized. At some of the towns in this county, as well as in adjoining localities, instead of a water master or overseer, a "field committee" is appointed to regulate the water during the crop season, thus leaving the distribution of the irrigating streams to a number of men, instead of to one man.

JUAB COUNTY is in the center of the western side of the territory and consists of a long, narrow strip extending westward from the Wasatch mountains across the desert to the Nevada line. The tilled land is mainly in Juab valley, in the extreme eastern end of the county, along the foot of Mount Nebo and the Gunnison plateau. A number of small streams issue from these mountain masses, the principal one, known as Salt creek, rising on the east side of Mount Nebo and flowing south and west around its base.

The agricultural lands are at an elevation of 5,000 feet and possess a climate similar to that of Salt Lake valley, to the north. Little, if any, land is cultivated without irrigation, the only exceptions being in the case of small areas of rye, corn, alfalfa, and wheat, which are reported to be raised without the artificial application of water, but which may possibly receive a small amount of moisture from springs or by seepage. The present water supply is insufficient for the needs of the land already tilled, and attempts have been made to build reservoirs, but with small success, as the dams for these are built in the cheapest manner possible and have been washed out by floods. The excess water of the spring, therefore, goes to waste, except such portions as may be turned upon grazing lands.

KANE COUNTY is on the extreme southern border of the territory, adjoining Arizona. It extends from the Colorado river westward, including the head waters of the Virgin. Like most of the country tributary to the Colorado, it consists of lofty plateaus, deeply eroded, and intersected by narrow canyons. As a consequence the streams flow for the greater part of their course far below the general level of the tillable lands. The cultivated areas are mainly in the western end of the county, on Kanab creek, and on Valley creek, a tributary of the Virgin. The irrigated land receives its water from these streams and the valleys being exceedingly narrow the ditches are necessarily small, extending along each side and covering small strips of land. Nearly all the valley land to which water can be brought is cultivated, and the water supply is ample for these limited areas. In the higher parts of the county there are a few localities in which corn, rye, and wheat are cultivated with partial success without irrigation, but in the towns, where the elevation is from 5,000 to 5,500 feet, irrigation is necessary for all crops or trees.

The expense of irrigation is very great in this county on account of the destructive floods, which rush without warning down the narrow canyons, sweeping out portions of the ditches, and at times even excavating channels to a depth of 50 or 60 feet, or even more, leaving the ditches high above the stream. It is only by constant expenditure and wonderful perseverance that settlements are maintained in these localities.

MILLARD COUNTY, like the other counties in the western part of Utah, extends from the mountain ranges of the central part of the territory westward to Nevada. In the center of the county is Sevier lake or sink, into which the Sevier river flows, the water being lost by evaporation, leaving a great deposit of saline matter. This river enters the county in the northeastern corner and flows southwestward. The amount of water carried is usually small, from the fact that the greater portion of the stream has been diverted upon lands in other counties through which it flows. Much of this county consists of broad deserts, from which rise short, abrupt mountain ranges. The soil is fertile, but on account of the lack of moisture it can not support the forms of vegetation useful to man. At the eastern end of the county, along the foot of the Pavant mountains, are a number of small towns dependent mainly upon agriculture and stock raising, receiving the necessary water from the little streams, whose waters are thus entirely used. Attempts have been made to increase the available supply from these streams by storing the floods in reservoirs, but many of the dams constructed for this purpose have been swept away.

The water of the Sevier river is used upon land in the canyon where it enters the county, and it is also diverted by dams into canals supplying the towns of Deseret and Oasis. The expense of maintaining these dams has been enormous. They have been washed out many times, and finally at great expense a new system has been constructed for the town of Deseret, the river being diverted from its original channel in order to insure greater stability in the headworks of the canal. Measurements of the discharge of Sevier river were made at Leamington (*a*), being thus above the points of diversion of the canals taking water from the river to lands northeast of Sevier lake.

Morgan county is in northern Utah, lying east of Davis county. The greater portion of the area is mountainous, agricultural land being found only along the Weber river and its tributaries, the principal of which is East Canyon creek. The valleys are very narrow, so that the tilled land is in long, narrow strips. Irrigating ditches are usually small and numerous, several ditches carrying the water that could be conveyed with greater economy in one large well located canal. The water is derived from Weber river and its affluents or from springs in the canyons. The area under cultivation exceeds that which can be supplied with water in all seasons, and unless there is an unusual snowfall in the mountains a portion of the crops is lost each year, except in the case of the irrigators owning prior rights. Water storage is needed, but the facilities for its construction are said to be very limited.

Economy of water under the present system seems to be impossible, as there are many small ditches, each independent of the other, and all constructed with the object of obtaining as much water as possible. For example, there are in the vicinity of Morgan 9 ditches, 4 on one side of the river and 5 on the other. Two well located and carefully built high line canals would probably furnish more water and cover a larger acreage. At present the water rights are in an unsatisfactory condition, and there is complaint of waste of water by those holding prior rights or those fortunately situated on the head waters.

Piute county lies north of Garfield county, and like it extends in a narrow belt from the Colorado river, including on the east the greater part of the drainage basin of the Fremont river and at its western end several valleys, through which flows the Sevier or its tributaries. The eastern part of the county consists principally of high plateaus cut by deep canyons, and it consequently contains but small areas of irrigable land. The towns are principally in the center of the county, near the head waters of the Fremont river, where the canyons are of less depth and the valleys sufficiently wide to give agriculture a foothold. A small portion of the head waters of the Fremont lies in Sevier county. Included in this area is Fish lake, a body of fresh water about 6 miles long and 1 mile wide. This is already used as a reservoir, a dam being constructed across its outlet by the irrigators along the river in Piute county.

---

a The quantity of water and its fluctuations are shown in the accompanying table:

DISCHARGE OF SEVIER RIVER AT LEAMINGTON, UTAH.

(Drainage area, 5,595 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
August 23 to 31	60	40	48	2,952	0.01	0.01
September	80	48	53	3,153	0.01	0.01
October	160	48	111	6,826	0.02	0.02
November	444	210	274	16,303	0.05	0.05
December	526	280	395	24,292	0.08	0.07
1890.						
January	1,058	280	625	38,437	0.13	0.11
February	1,140	567	713	39 571	0.13	0.13
March	690	567	630	38,745	0.13	0.11
April	976	608	726	43,197	0.14	0.13
May	2,329	976	1,705	104,857	0.35	0.31
June	2,206	649	1,250	74,375	0.25	0.22
July	649	185	346	21,279	0.07	0.06
August	185	150	153	9,409	0.03	0.03
September	185	150	157	9,342	0.03	0.03
October	362	185	310	19,065	0.06	0.06
November	403	321	373	22,194	0.07	0.07
December	649	403	509	31,304	0.10	0.09
Per annum	2,329	150	625	451,775	1.49	0.11
1891.						
January	772	649	735	45,202	0.15	0.13
February	772	772	772	42,846	0.14	0.14
March 1 to 28	772	526	618	38,007	0.13	0.11
April 5 to 30	608	526	563	29,928	0.10	0.09
1891.						
May	1,386	608	1,114	68,511	0.23	0.20
June	1,140	567	952	56,644	0.19	0.17
July	526	140	297	18,265	0.06	0.05
August	245	140	195	11,992	0.04	0.03
September	185	160	175	10,412	0.03	0.03
October	210	185	202	12,423	0.04	0.04
November	403	210	312	18,564	0.06	0.06
December	813	403	551	33,886	0.11	0.10
Per annum	1,386	140	535	386,080	1.20	0.10
1892.						
January	1,058	813	1,016	63,485	0.21	0.18
February	1,017	895	931	53,532	0.18	0.17
March	854	608	738	45,387	0.15	0.13
April	567	100	232	13,804	0.05	0.04
May	1,017	80	250	15,375	0.05	0.04
June	1,222	210	718	42,721	0.14	0.13
July	210	48	88	5,412	0.02	0.02
August	80	48	53	3,250	0.01	0.01
September	60	48	49	2,915	0.01	0.01
October	80	48	53	3,259	0.01	0.01
November	120	100	117	6,961	0.02	0.02
December	976	140	570	35,055	0.12	0.10
Per annum	1,222	48	401	291,165	0.97	0.07

The valleys of the western end of the county are comparatively broad and receive waters from numerous small streams which enter the Sevier from both sides. In the valley through which the Sevier river flows the ditches are generally taken out from the small streams rather than from the river itself, both for the sake of convenience and economy. Being near the head waters, most of the farms have an ample supply of water, and thus there is less demand for storage, but many farmers are apprehensive that with the development of irrigation in Garfield county they will not be able to receive their usual supply. The county contains a large number of excellent reservoir sites, notably on Otter creek, which flows from Sevier county. The lack of coincidence of the county lines with lines of drainage leads to many complications, since the reservoir sites needed by this county are in some cases beyond its jurisdiction, while in turn it contains reservoir sites of no use to its own people, but of great value to others.

RICH COUNTY is in the northeastern corner of Utah, adjoining Idaho and Wyoming. The agricultural land in this county lies in two valleys, separated by the Bear River plateau. On the east of this plateau is the Bear River valley and on the west is Bear Lake valley. The greater portion of this latter valley is in Idaho, there being a comparatively narrow strip of land along the southern and western shores of the lake. Bear River valley is a broad, open tract of country, lying at an elevation of nearly 7,000 feet. The climate is somewhat cold, but the hardier crops flourish. The water supply is derived from Bear river, which flows from south to north, and from numerous tributaries rising in the mountains to the west of the river.

In Bear Lake valley, in the vicinity of Laketown, are irrigated farms of considerable size. North and east of this place, however, the shores of the lake rise abruptly, leaving little room for agriculture. To the west of the lake, however, the slopes are more gentle, and the irrigated land extends in a long, narrow strip, receiving water from small streams and springs in the canyons. There are a number of notable springs in this county, due to the peculiar structure of the mountains and the prevalence of limestone, which in places has been dissolved, giving rise to underground water courses of considerable size, carrying in one case as high as 50 second-feet.

SALT LAKE COUNTY is southeast of Great Salt lake and lies between the summits of the Wasatch mountains on the east and the Oquirrh mountains on the west. On the south it is bounded by a transverse range of hills, through which the Jordan river has cut a deep notch. The agricultural land is at an elevation of from 4,300 to 5,000 feet, and enjoys a climate of the most favorable character, since from its central position and elevation it is not subject to great extremes of heat and cold. The natural facilities for irrigation in this county are not surpassed by those of any valley in the arid regions.

The water supply comes from two sources. The first consists of the various streams which issue from the Wasatch mountains, on the east of the county, flow westward through narrow canyons, and finally enter the valley, where, before irrigation was practiced, the water gradually disappeared into the sand, or in times of flood flowed into the Jordan river. The second source of supply is the Jordan river, the outlet of Utah lake, situated in the county of Utah. The water from this river is carried to the farming land by 5 large canals, 2 on the east side and 3 on the west, as well as by a multitude of small ditches, a few of which furnish power to mills.

Although the natural advantages of the water supply are almost unexcelled, yet the utilization of these advantages has not been of the most satisfactory character, from the fact that the irrigating systems have sprung up without plan and have been developed solely with reference to the needs of the individual owners, and not with regard to the general good of the county. For example, water which could be used on the high bench lands is taken from mountain streams down to the low lands beneath the level of canals taking water from Utah lake. The irrigating ditches thus cross each other, giving rise to complications and waste in construction, and water which might be employed to better advantage upon the higher lands is taken to the farms which apparently should be irrigated by lake water.

Utah lake is the great natural reservoir for Salt Lake county, and upon the proper utilization of its waters depend the prosperity and future extension of the farming land of that county and to a less degree the growth of the city of Salt Lake. Up to the present time, although the need of improving the water supply has been appreciated, no serious attempts or definite plans toward this end have been made. The employment of Utah lake as a reservoir, so that the water shall be used to the best advantage, is not a simple engineering problem, but is complicated by the fact that vested rights to its waters have been acquired by individuals and corporations, who can scarcely be expected to work in harmony, and, further, much of the land surrounding the lake and adjacent to its outlet has passed into the hands of proprietors whose interests are apparently antagonistic to those of the farmers of Salt Lake valley.

The control of the lake has been a source of dispute for many years between the two counties. On the one hand, the farmers of Salt Lake county deemed it necessary to hold back as much as possible of the flood waters in the lake, and, on the other hand, the residents of Utah county owning land around the lake wished to have the waters flow freely through the Jordan, in order that the lake might fall and the area of pasture lands be as large as possible. The contentions between these two parties finally culminated in a lawsuit for damages for injury caused by flooding lands in Utah county. The matter was finally settled by arbitration, and a compromise was agreed upon in 1885, by which a board of commissioners representing both counties was empowered to regulate the height of the water in the lake and to hold it at a certain level. If the water should at any time be maintained at a higher level than agreed upon, the damages, if any, to the land in Utah county must be paid by the owners of the dam in the Jordan river.

Under the act of Congress of October 2, 1888, the lake and the surrounding lands were segregated as a reservoir. A survey of the shores was made by the United States Geological Survey and a study of the hydrography of that drainage basin was begun. The conclusions reached were, that to serve its best purposes as a reservoir the lake should be drawn to a lower level on account of the enormous evaporation from the present water surface, the supply of the lake not being in many seasons sufficient to counterbalance this enormous loss. At the same time, to provide storage room for unusual floods, the land below high water mark should be withheld from settlement and entry.

In consequence of uncertainties attending the amount and distribution of the water in complicated and wasteful ditch systems, there are great losses of crops, especially among the farmers owning second and third rights, and these irrigators complain bitterly of the apparent lack of economy among the older settlers, who enjoy prior rights. The majority of the farmers in the valley state that the way out of their difficulties is by a more careful and just regulation of the water and by the storage of the excess waters of the spring floods. They discuss the methods of water storage, especially in the reservoir sites at the head of the Cottonwood creeks, reserved for this purpose by the government, and express hopes of ultimately constructing dams for water storage in the more favorable localities. Experience has shown that, owing to the gradual accumulation of moisture in the soil, less water is required to irrigate an acre than formerly, and therefore a far larger acreage is now cultivated than appeared possible in the early history of the valley.

San Juan county is in the southeastern corner of the territory, adjacent to Colorado, New Mexico, and Arizona. Settlement has progressed but slowly, as the arable lands have not been thrown open to agricultural entry to any considerable extent, and possible settlers have been deterred from entering upon them by the uncertainty as to the reservation of lands for the Ute Indians.

The San Juan river crosses the southern part of the county, flowing into the Colorado river, which forms the western boundary of the county. There is usually an ample supply of water in this river, but the bottom lands being narrow and the channel shifting in every flood the expense of bringing water upon the land is generally too great for the area to be cultivated. On account of the difficulty and expense of bringing water from the river by canal, it is a question among the farmers as to whether it would not be advisable to attempt to raise the water by machinery rather than try to build new dams each year in the unstable sandy channel. Along the tributaries of the San Juan and in the higher valleys a small amount of land is brought under irrigation. Stock raising, however, is the principal industry.

Sanpete county is in the center of Utah, and is the most southerly of the chain of thickly settled counties which, beginning with Cache county on the north, extends in a generally southern direction. The county includes the whole of the catchment area of Sanpitch river and a portion of the valley of the Sevier river, both above and below the junction with the Sanpitch. The agricultural land lies along these rivers and their tributaries and has an elevation of from 5,000 to 6,000 feet.

The Sanpitch valley is watered by various small streams, which issue through canyons leading down from the Wasatch plateau on the east. Between the Sanpitch valley and the Sevier is the Gunnison plateau, which, however, is not of a height sufficient to give rise to perennial streams of importance. The west side of the valley, therefore, receives very little water, and the principal towns are along the eastern edge of the agricultural lands. At the mouth of each canyon from which a creek issues a settlement has been made, and many of these have been incorporated as cities, the inhabitants, however, depending almost entirely upon the cultivation of the surrounding fields or upon sheep and cattle raising. The municipality controls the waters of the creek and apportions them to the town lots or fields in accordance with regulations made by the voters. The control of the water is under the direct supervision of a water master and his deputies, who regulate the head gates of the various ditches, turning the water to the users according to a schedule previously prepared. The water supply of each city and its surrounding fields is wholly within the control of the people, and they have no one but themselves to consult in regard to its conservation or employment. They may construct storage works, improve the channel, or make any regulations desired.

The conditions of control in that portion of the county situated in the Sevier valley are in marked contrast to those just mentioned in the Sanpitch valley, for here the water supply is received, not from independent sources, which can be controlled without interference, but from the Sevier or Sanpitch river, after having passed by the canal head works and agricultural lands of various irrigators. The waters of the Sevier river are used in three counties before reaching Sanpete county, and, therefore, there is but little available except in flood seasons. There is two or in places three times as much land under cultivation in the Sanpitch valley as can be supplied with water in ordinary seasons. It has become customary to let one-half the fields lie fallow for a year while the other half is being used, the fallow land being plowed once or twice in order to destroy the weeds. The water supply is scanty even for one-half the land, and the right to take water from each creek, by increase of settlement and subdivision, has become so complicated and has been so extended that it is difficult even for those owning prior rights to get sufficient water to mature a fair crop. It is even worse with the later settlers, for, according to the regulations, they are only allowed the flood waters or such portions of the stream as their neighbors can not use. After a late comer has used the water for several years and has established a home it becomes a matter of great difficulty, both legally and actually, to deprive him of water, destroying his trees and fields, in order that the older settlers shall have enough, and yet, on the other hand, irrigators holding prior rights feel that it is not just for other men to come in and gradually destroy the value of their farms by acquiring the greater part of the water.

Sanpete county is a good example of the evils arising from the neglect of jealously guarding prior rights. As population increased, the older farmers, from friendship or compassion, allowed others to share their water supply, and frequently in times of scarcity good naturedly divided the scanty supply. Thus an increasingly large number of irrigators acquired certain rights to the water, until the limit has been reached, when in dry seasons all suffer together, and at other times there is barely enough water for all, and they do not receive sufficient returns to insure prosperity or contentment. Storage reservoirs and other projects for increasing the supply have been attempted. A number of reservoirs, all of small size, have been constructed or are now being made in various parts of the county. Owing to lack of experience and engineering skill several of the dams of these reservoirs have been swept away by floods, with considerable damage to property, while others have been so located that there is not a sufficient amount of water to fill the basin.

SEVIER COUNTY is in the central part of the territory, and includes the principal valley along the course of the Sevier river. In this broad valley are a number of towns of considerable size, all depending upon agriculture. Many canals receive water from the river, and various small ditches are fed from springs and streams which issue from the mountains on each side. Only a small portion of the valley land is tilled, thousands of fertile acres lying idle for want of water. Farming communities depending upon the smaller streams utilize them to their fullest extent, small reservoirs being built in various places to hold the flood waters until needed for maturing crops. The irrigators who depend upon the Sevier river do not enjoy the same security in regard to the permanence of their water supply, as agriculture is rapidly being developed above them in the valleys of Garfield and Piute counties, and thus the summer flow of the river tends to diminish.

There is a feeling of insecurity in regard to water rights along this large river, since settlers are pushing into every little valley and diverting upon their lands the springs or streams which formerly flowed into the river, thus tending to decrease the amount flowing through the lower valleys. At the same time, ditches along the course of the river are being enlarged and gradually extended to cover new land, and occasionally a new canal is built by an association of farmers, who, by better organization and co-operation, necessarily gain strength and importance, and by acquiring old water rights in one way or another diminish the amount available for the smaller ditches.

SUMMIT COUNTY is in the northeastern part of Utah, surrounding on two sides the re-entrant angle formed by the corner of Wyoming, which appears to encroach upon the territory of Utah. This county includes the head waters of Bear river, Weber river, and the principal branch of the Provo. The agricultural land is along the comparatively narrow valleys of these streams and their tributaries, receiving water from them or from the numerous springs issuing from the sides of the mountains.

The general elevation of agricultural land is from 5,500 to 7,000 feet, while the mountains rise to heights of from 10,000 to 13,000 feet. The water supply of this rugged country is generally ample at all times of the year, although in the lower valleys losses of crops have occurred. In 1889 the losses were especially great in this and the counties adjoining. Attempts were made by the irrigators of the lower counties to restrain the farmers of Summit county from using all the water, so that some might flow to the dry fields below. Men came up the river at that time with the intention of closing the head gates of the various ditches, but the attempt was not a success, and it does not appear that the irrigators of the lower counties were benefited.

Attempts have been made in a small way to store water, and several irrigators report that they are depending upon water from their own reservoirs and are increasing the supply by building new and better dams. The washing out of one dam, and consequent loss of property, have taught the farmers that great care must be used in these undertakings. Small crops of wheat and oats are occasionally raised without irrigation, but this method is very uncertain, and the yield is small unless there happens to be an unusual amount of rain. The success of farming, either with or without irrigation, depends directly upon the amount of precipitation. Whenever the snowfall during the winter is heavy, farmers look forward to a prosperous season, and when the snowfall is light, as it has been for several years, the prospects are discouraging, since the greater portion of the snow melts and runs away in the spring before the water is needed. In the upper valleys the seasons are short, frosts occurring late in the spring and early in the fall, rendering agricultural success a matter of uncertainty.

TOOELE COUNTY is southwest of Great Salt lake and includes the greater part of the desert of the same name. The county extends from Oquirrh mountains on the east to the Nevada line on the west. It includes a number of small mountain ranges, rising abruptly from the broad and nearly level valleys and having a general north and south trend. The county lies almost within the center of the area formerly covered by the waters of the fresh water lake known to geologists as Lake Bonneville, and the soil of the broad valleys and deserts was deposited by these waters. The mountain ranges were islands in the lake, and still show the results of wave action in the broad terraces, successive beaches of the lake. The soil in the valleys is very fertile, but is heavily charged with alkaline salts, so that care must be taken in applying water. On the terraces the soil is usually not so good, but it is comparatively free from alkali and is cultivated to a small extent.

The water supply of this county is very limited, so that a very small portion of the broad, fertile valleys can be irrigated. Along the foot of each mountain range there are a few springs which are utilized either for watering stock or, if sufficiently large, for irrigation. The mountain ranges do not rise to a height sufficient to receive a very heavy snowfall, and consequently the streams from them are small in size and variable in quantity. There is a prevailing opinion among the farmers that by driving tunnels into the mountains and cleaning out the springs the water supply can be increased. This is undoubtedly the case where, for example, the strata dip away from the valley and tend to carry the small amount of water which may be percolating through the rocks away to the opposite side of the mountains.

The cost of irrigation in this county is very great on account of the numerous failures to obtain sufficient water or the destruction of ditches by unexpected floods. Valley bottoms are at an altitude of about 4,200 feet, being but slightly above the level of Great Salt lake. The climate is extremely arid, and there is a considerable range of temperature, frosts sometimes occurring late in the spring or early in the fall, in spite of the high temperature prevailing during the summer. Among the mountains small acres of rye, wheat, and corn are cultivated without irrigation, although the yield is small and may not repay the labor of tilling the soil, unless the season happens to be unusually rainy. Some alfalfa is also raised in the same way, the cuttings being only from one-half to three-quarters of a ton to the acre, while on irrigated land they are 2.5 tons.

The principal towns are in the eastern end of the county, in Tooele and Rush valleys. They depend for their life largely upon mining and stock raising, the cultivation of the soil being of secondary importance. In the extreme western end of the county, on Deep creek, and especially in the vicinity of Ibapah, is a small amount of agriculture, the supplies being readily marketed at the Deep Creek mines.

UINTA COUNTY is in the northeastern corner of the territory, adjoining Wyoming and Colorado. The mountain range of the same name crosses the northern end of the county, while the southern and western parts are covered by the Ute Indian reservation, thus leaving but a small portion of the county open to agriculture. The tilled land is mainly along Brush creek and Ashley fork, both of which flow into Green river. Water is taken from these smaller streams, as they can be readily controlled. Green river crosses the northeastern corner of the county and then flows diagonally through the county from northeast to southwest. Its waters, however, are in general too far below the agricultural land to be taken out, or at places where diversions may be feasible the expense has been too great for the present inhabitants.

UTAH COUNTY embraces some of the best agricultural land of the territory, its principal valley equaling if not excelling in advantages of location and water supply any other valley in the territory. This county is south of Salt Lake county and extends from the summits of the Wasatch westward to the Oquirrh range. In the center is the beautiful body of fresh water known as Utah lake, on the western shore of which is a short mountain range rising about 3,000 feet above the valley and known as the Lake mountains. These divide the county into two portions, Utah valley, containing Utah lake, on the east, and Cedar valley on the west. The contrast between these valleys is striking, the one with its well watered fields and broad lake, the other almost a desert, with but few small towns and limited agricultural possibilities. In soil and climate there is no appreciable difference, and it is the water supply alone that gives the great superiority to the valley on the east.

The natural water supply of this county is excellent, but farmers claim that the water is not distributed with due regard to economy or apparent equity. The greatest cause of loss is the duplication of canals, two, three, or even four small canals running in general parallel courses and carrying the water to land that one large canal would serve with far greater economy. As a consequence of the large number of ditches the construction is usually poor and the headworks and flumes are of temporary character. The dams and head gates are occasionally washed out or injured in floods, or, for instance, by the railroad ties which are floated down the river at the time of the spring freshets. In consequence of these injuries crops have been lost before the damage could be repaired.

The principal streams watering this valley are the American fork, Provo or Timpanogus river, Hobble creek, Spanish fork, and Salt creek. The Provo is by far the largest river. It drains an extensive area to the east of the main range of the Wasatch, through which it cuts a deep canyon. The excess water of these rivers, together with the drainage from the fields, finally finds its way into Utah lake, the regulation of which is mentioned in the description of Salt Lake county. There is more arable land than can be watered by the regulated flow of the rivers, and, as a consequence, the area of tilled land has increased until limited by the amount of water available in ordinary seasons. In times of drought, therefore, the land more recently brought under cultivation can not produce a crop, and considerable suffering exists among the later settlers.

Under the well established customs of Utah, previously mentioned, the water supply is given to those farmers who have used it the longest, the rights of each man being classed as first, second, or third, according to local regulations. In times of drought, as during 1888 and 1889, the farmers having only third rights lost their crops and most of their trees and vines, except such as were watered by hand. Those holding secondary rights also lost heavily, and even among those having first or prior rights the water was not sufficient for all demands.

Many of the larger irrigation works of Utah valley, as well as those of Salt Lake valley, are owned in part by persons who do not personally cultivate land, but who annually rent their water rights at the market value. There is no fixed price, the rental being a matter of agreement between the parties interested. Thus the owner of water rights may rent his rights to one irrigator for a given season and to another the next. These water rights, or, more properly, shares of stock in the canal, are supposed to entitle the owner to a certain amount of water, each share being intended originally to furnish water for one acre. In times of scarcity, however, one share of stock may actually furnish water sufficient for only one-third or perhaps one-fifth of an acre, and even, in some instances, for only one-seventh of an acre. There is very little dry farming in this county. A small acreage of wheat is planted in the fall and is sometimes successful.

The lower lands of Utah valley were first brought under cultivation and have prior rights to the water. After these were taken up agriculture began to encroach upon the higher bench lands or shores of the ancient Lake Bonneville, and later canals were taken out to water these benches, many of them, however, having rights only to the surplus water. The irrigation of the higher lands has a tendency to moisten the lower fields, and when an excessive amount of water is applied during the flood season the water slowly appears on the lands below, and later in the season may saturate those so completely as to make pasturage, or even injure it by creating marshes or by developing an alkaline crust. Thus in the future development drainage must be inaugurated as well as an improved system of distributing the water.

Water conservation has been attempted in a small way, and several reservoirs have been built in suitable places, by means of which a few farms have been successfully cultivated. Many sites are favorable for this purpose. In one or two instances attempts have been made with little success to increase the ordinary summer flow by tunneling into the mountains. On the lower lands, especially near the lake, there are a large number of flowing wells, which are useful not only for domestic supply and watering cattle but to a small extent for irrigation. They are confined mainly to lands so low that they are already wet by seepage. The well water is usually stated to be not as good as that from ditches, on account of its slightly saline qualities and lack of fine fertilizing sediment. (a)

WASATCH COUNTY is east of Utah county, the greater portion of it being included within the catchment area of the Duchesne river and its tributaries, a part of the Colorado drainage. Nearly all the county lies within the Uinta Indian reservation, but on the western end a small projection of the county lines extends across

---

a Observations on the flow of various streams are given in the following tables:

TABLE 1.—DISCHARGE OF PROVO RIVER ABOVE PROVO, UTAH.

(Drainage area, 640 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
July 27 to 31	150	149	150	9,225	0.27	0.23
August	140	144	145	8,917	0.26	0.23
September	174	144	150	8,925	0.26	0.23
October	200	174	180	11,070	0.32	0.28
November	280	200	224	13,328	0.39	0.35
December	630	240	384	23,616	0.60	0.60
1890.						
January	700	200	305	18,751	0.55	0.48
February	564	280	377	20,923	0.61	0.59
March	700	240	519	31,918	0.93	0.81
April	1,240	500	840	49,980	1.46	1.32
May	2,180	1,316	1,926	118,450	3.47	3.01
June	2,260	440	1,184	70,446	2.06	1.85
July	440	280	314	19,311	0.56	0.49
August	280	240	252	15,498	0.45	0.39
September	280	240	244	14,518	0.43	0.38
October	330	280	304	18,696	0.55	0.48
November	330	280	303	18,028	0.53	0.47
December	330	240	293	18,020	0.53	0.46
Per annum	2,260	200	572	414,541	12.13	0.89
1891.						
January	280	240	255	15,682	0.46	0.40
February	500	280	311	17,240	0.50	0.48
March	1,316	280	492	30,258	0.89	0.77
April	930	280	478	28,430	0.83	0.75
May	1,704	851	1,226	75,399	2.21	1.92
June	1,470	851	1,190	70,805	2.07	1.86
July	1,240	200	423	26,014	0.76	0.67
August	280	200	260	15,990	0.47	0.41
September	440	280	314	18,683	0.55	0.49
October	380	330	364	23,386	0.68	0.57
November	380	380	380	22,610	0.67	0.60
December	380	330	343	21,094	0.62	0.54
Per annum	1,704	200	503	365,501	10.71	0.79
1892.						
January	330	330	330	20,295	0.59	0.52
February	380	330	351	20,182	0.59	0.55
March	440	330	361	22,201	0.65	0.57
April	440	330	377	22,431	0.66	0.59
May	1,780	774	1,079	66,358	1.95	1.68
June	1,626	1,316	1,511	89,905	2.64	2.37
July	1,240	200	441	27,121	0.80	0.69
August	280	174	201	12,361	0.36	0.31
September	240	200	201	11,959	0.35	0.31
October	280	200	241	14,821	0.43	0.38
November	280	240	279	16,600	0.49	0.44
December	330	240	257	15,805	0.45	0.40
Per annum	1,780	174	469	340,039	9.96	0.73

the head waters of the Provo river, and it is in this small corner of the territory that the principal towns and agricultural areas are situated.

The valley of the Provo at this point is comparatively broad, and the river, rising in the Uinta range, furnishes water sufficient to supply all or nearly all the land to which it can be taken. Along the tributaries of the Provo, however, are tracts of land for which the water supply is insufficient, and attempts have been made to increase this by small reservoirs among the mountains. The facilities for the construction of these are unusually good, from the fact that there are a number of small lakes and depressions of glacial origin whose outlets can readily be closed. It is estimated that the water can be stored at an expense of $10 per acre of land irrigated. Besides the use of reservoirs, the attempt has been made to increase the amount of water available by cutting a ditch and tunnel across the divide and bringing the head waters of Strawberry creek, a branch of the Duchesne, over to the Provo side. In this way the demand for water, which is most strongly felt in July and August, can be in part supplied.

WASHINGTON COUNTY is in the southwestern corner of Utah, and includes the greater part of the drainage basin of the Virgin river. The agricultural lands are at an elevation of from 2,500 to 3,000 feet or more, and are mainly along narrow valleys between lofty mountain ranges. The Virgin river on the east drains a part of the high plateau of southern Utah, and thus flows in deep, narrow canyons, while its tributaries on the west receive water from steep mountains, which are almost entirely free from forests. The river is thus subject to violent floods whenever a heavy storm occurs, and at these times carries large quantities of sand and débris, cutting the banks and washing away or obliterating the irrigating ditches.

The climate of the valleys is very warm, the growing season being sufficiently long and hot to insure the success of cotton and semitropical fruits. The area of good land, however, is comparatively limited, and the unregulated water supply barely sufficient for the present area under cultivation. The irrigators, however, believe that water storage in side canyons and depressions not on the line of the streams can be successfully accomplished and larger areas thus brought under cultivation. On account of the erratic character of the streams the expense of maintaining the ditches and diverting water into them has been very great. The head works are frequently washed away, and several ditch owners state that they scarcely ever take water into their ditches at the same place two years in succession. As in the case of the other counties in the Colorado basin, the streams occasionally wash out their channels to a depth of many feet, necessitating the construction of long lines of canal to bring the water upon the land again. Stock raising and the cultivation of the soil are the principal industries, mining and milling of gold ores having diminished in importance.

WEBER COUNTY, in the northern part of the territory, includes some of the most easily watered lands in Utah, the supply coming mainly from the Weber and its principal tributary, Ogden river, both issuing from deep

TABLE 2.—DISCHARGE OF AMERICAN FORK AT BRIDGE IN CANYON, UTAH.

(Drainage area, 66 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
August	66	10	38	2,337	0.66	0.58
September	48	20	30	1,785	0.51	0.45
October	66	6	33	2,029	0.58	0.50
November	30	30	30	1,785	0.51	0.45
December	108	30	67	4,120	1.17	1.02
1890.						
January	276	30	62	3,813	1.08	0.94
February	108	48	72	3,996	1.13	1.09
March 1 to 29	192	66	117	7,195	2.04	1.77
April			*380	22,610	6.43	5.76
May	885	465	666	40,990	11.62	10.11
June			*208	12,360	3.51	3.16
July			*45	2,765	0.78	0.68
Per annum	885	6	146	105,785	30.02	2.21

* Estimated.

TABLE 3.—DISCHARGE OF SPANISH FORK IN CANYON, UTAH.

(Drainage area, 670 square miles.)

1889.						
September	70	45	50	2,975	0.08	0.07
October	70	50	62	3,813	0.11	0.09
November	70	45	53	3,153	0.09	0.08
December	70	50	67	4,120	0.12	0.10
1890.						
January	230	50	68	4,182	0.12	0.10
February	95	50	76	4,218	0.12	0.11
March	355	50	143	8,794	0.25	0.21
April	770	150	387	23,026	0.64	0.58
1890.						
May	1,040	355	777	47,785	1.34	1.15
June	355	110	205	12,197	0.34	0.31
July	590	82	114	7,011	0.20	0.17
August	82	50	64	3,837	0.11	0.10
September	95	50	63	3,748	0.10	0.09
October	95	50	64	3,936	0.11	0.10
November	50	50	50	2,975	0.08	0.07
December 1 to 13	50	50	50	3,075	0.09	0.07
Per annum	1,040	50	172	124,784	3.50	0.25

canyons in the Wasatch range and uniting shortly after. The principal agricultural land is adjacent to these rivers, between the foot of the Wasatch mountains and Great Salt lake. In addition to this there is a large open valley on the head waters of Ogden river, being thus on the east side of the range. The quantity of water from these rivers, although large, has not proved to be sufficient for all of the land under cultivation. In the latter part of June need of more water is felt and in July and August there is often loss of crop. A number of large canals have been built from one or the other of the rivers, but most of these large systems have rights secondary to those of smaller claimants, and it thus has happened that, as in 1889, injunctions were obtained restraining one or more of these large canals from taking any water from the river. This has resulted in great loss to the farming communities not only by the injury to crops and trees but also in legal expenses. The amount of water flowing in these two rivers has been computed from measurements made by the United States Geological Survey. (*a*)

---

a The gauging station of the Ogden river was in the canyon near the powder mills above the city of Ogden and gave the total discharge of the stream. The results are shown in the following table:

DISCHARGE OF OGDEN RIVER AT POWDER MILLS, UTAH.

(Drainage area, 360 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
August 9 to 31	60	40	50	3,075	0.16	0.14
September	70	50	52	3,094	0.16	0.14
October	145	70	89	5,473	0.28	0.24
November	253	60	105	6,247	0.33	0.29
December	735	145	421	25,891	1.35	1.17
1890.						
January	510	289	382	23,493	1.22	1.06
February	1,364	399	680	37,740	1.97	1.89
March	1,401	362	978	60,147	3.13	2.72
April	1,919	1,068	1,449	86,215	4.49	4.02
May	2,178	1,475	1,818	111,807	5.82	5.05
June	1,438	624	910	54,145	2.82	2.53
July	624	326	458	28,167	1.47	1.27
August	473	215	312	19,188	1.00	0.86
September	235	195	206	12,257	0.64	0.57
October	326	215	265	16,297	0.85	0.74
November	267	235	255	15,172	0.79	0.71
December	....	....	*240	14,760	0.77	0.67
Per annum	2,178	195	663	479,388	24.97	1.84

* Estimated.

The gauging station on Weber river was above the railroad station of Uinta, about 10 miles southeasterly from Ogden. The results of the measurements are shown in the following table:

DISCHARGE OF WEBER RIVER IN CANYON ABOVE UINTA, UTAH.

(Drainage area, 1,600 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
October 13 to 31	290	130	181	11,131	0.13	0.11
November	290	160	208	12,376	0.14	0.12
December	815	200	430	26,445	0.31	0.27
1890.						
January	815	290	457	28,105	0.33	0.29
February	1,400	200	547	30,358	0.36	0.34
March	2,130	200	1,091	67,096	0.79	0.68
April	4,280	970	2,184	129,948	1.52	1.36
May	5,465	3,470	4,528	278,472	3.26	2.83
June	3,635	1,220	2,017	120,011	1.41	1.27
July	1,220	290	549	33,763	0.40	0.34
August	450	200	280	17,220	0.20	0.18
September	290	2,400	265	15,767	0.18	0.17
October	450	200	331	20,356	0.22	0.21
November	340	290	298	17,731	0.21	0.19
December	340	240	290	17,835	0.21	0.18
Per annum	5,465	200	1,070	776,662	9.09	0.67
1891.						
January	450	290	303	18,634	0.23	0.19
February	1,220	290	461	25,586	0.30	0.29
March	1,220	450	625	38,437	0.45	0.39
April	2,420	520	1,502	89,369	1.05	0.94
May	4,655	1,940	2,752	169,250	1.98	1.72
June	2,225	1,135	1,621	96,449	1.13	1.01
July	1,265	395	844	51,906	0.61	0.53
August	520	240	338	20,787	0.24	0.21
September	520	290	402	23,919	0.28	0.25
October	665	520	599	36,838	0.43	0.38
November	665	520	573	34,093	0.40	0.36
December	665	520	534	32,841	0.39	0.33
Per annum	4,655	240	880	638,109	7.49	0.55
1892.						
January	890	520	599	36,838	0.43	0.37
February	890	520	695	39,962	0.47	0.43
March	1,220	590	800	49,200	0.58	0.50
April	1,220	450	900	53,550	0.63	0.56
May	5,755	590	2,705	166,357	1.95	1.69
June	4,530	2,035	2,867	170,586	2.00	1.79
July	2,035	160	819	50,368	0.59	0.51
August	160	100	239	14,698	0.17	0.15
September	200	160	187	11,126	0.13	0.12
October	290	200	240	14,760	0.17	0.15
November	450	290	357	21,241	0.25	0.22
December	890	395	476	29,274	0.34	0.30
Per annum	5,755	100	907	657,960	7.71	0.57

WASHINGTON.

[THIRTEEN EASTERN COUNTIES ONLY.]

Total population (average per square mile 3.56)		116,889
Number of farms (9.15 per cent of population)		10,692
Number of irrigators (9.78 per cent of farm owners, 0.89 per cent of population)		1,046
Area (32,842 square miles)	acres..	21,018,880
Area irrigated in census year	do...	48,799
Area of all farms, 49.90 per cent improved	do...	2,921,759
Cereals raised in census year, including 1,449 acres in rye	do...	460,082
Barley, average production, 24.51 bushels per acre	do...	50,871
Corn, average production, 16.32 bushels per acre	do...	9,320
Oats, average production, 24.94 bushels per acre	do...	38,541
Wheat, average production, 17.04 bushels per acre	do...	359,901
Alfalfa	do...	2,924
Total value of all farms, including land, fences, and buildings		$44,016,920
Estimated total value of the farms irrigated in whole or in part		$2,440,000
Estimated value of all farm productions (sold, consumed, or on hand) for 1889		$8,386,100
Estimated value of productions, as above, from farms irrigated in whole or in part		$834,000
Average size of irrigated farms	acres..	47
Average size of irrigated farms of 160 acres and upward	do...	324
Per cent of acreage of irrigated farms of 160 acres and upward to total acreage irrigated		34.54
Average size of irrigated farms under 160 acres	acres..	32
Average first cost of water right per acre		$4.03
Average annual cost of water per acre		$0.75
Average first cost per acre of preparation for cultivation		$10.27
Average value of irrigated land, including buildings, etc., in June, 1890, per acre		$50.00
Average annual value of products per acre in 1889		$17.09

As in the case of Oregon, the eastern counties of the state in which irrigation is practiced are grouped together and used under the name of the state in making the comparisons of the condition of irrigation in the census year. In number of irrigators this state stood at the foot of the list, having a few less than the territory of Arizona, and also had the smallest acreage of the 11 states and territories described. In value of lands irrigated the state occupied an intermediate position, while in average value of products it stood high, as should follow from the relatively small average size of irrigated farms. A considerable portion of the land was devoted to fruit culture, and as a whole irrigation, being in its experimental stages, was conducted with perhaps more care than in the adjoining states. The proportion of land owned by irrigators which was actually watered was small, only 17 per cent, so that the acreage cultivated in this manner could be greatly increased without adding to the number of persons using water. The first and annual cost for water was exceedingly small, in this respect the state coming next to Wyoming.

GENERAL DESCRIPTION.

The state of Washington, at least in its southern half, is similar to Oregon in climate and topography. The most conspicuous feature of surface relief is the Cascade range, which trends in a direction a little east of north across the state and at a distance of from 120 to 150 miles from the ocean. This range divides the state into two great parts, differing in climate and agricultural capabilities. On the western side of the range the annual precipitation is heavy and a dense forest covers the mountains and smaller hills, while east of the mountains the rainfall is much less and vegetation is comparatively scanty.

The great plains of the Columbia form the most striking topographic feature. These extend from the foothills of the Cascade range eastward to the mountains of Idaho, and from the mountainous or broken region below the border of British Columbia southward across the state. The Columbia river coming from the British possessions flows in a direction a little west of south until it has fairly entered the plain or plateau region, where it is diverted sharply toward the west, and with many meanderings it flows for some distance in the latter direction, then bends toward the south and southeast, describing roughly a half circle around the greater part of these high plains. Throughout this distance the river has cut for itself a deep gorge, in which it flows from 1,000 to 2,000 feet below the general level.

These plains owe their existence, in part at least, to extensive sheets of lava, which in former times flowed out over portions of southern Idaho, eastern Oregon, and Washington, filling pre-existing valleys and burying the older sedimentary beds. These sheets of basaltic rocks now stretch from the Cascade range away to the eastward and southeastward to the limiting mountain ranges which lie to the west of the Rockies. The surface features to a large extent have been modified by deformation and erosion of the rocks, and also by the sedimentation in lakes of comparatively recent geologic time, some of which lakes have been of large area. In many places the basaltic rocks are deeply carved by former drainage channels known as "coulees," having steep, almost vertical walls of several hundred feet in depth. The bottoms of these coulees, however, are far above the level of the Columbia, to which stream their relation is not yet evident. Much of the drainage on the surface of the plains is of the lost river type; that is to say, the streams flow into some small lake or swamp from which the water is lost by evaporation or disappears by percolation or by channels through or between layers of the basaltic rocks.

The water supply of the plains of the Columbia is exceedingly small. In the river itself there is an amount sufficient for all the needs of irrigation should it be possible or desirable to introduce it, but unfortunately the river is hundreds of feet below the level of the arable land and its waters can be taken out only upon a very narrow strip of sandy bottoms. The estimated summer discharge of the river at a point above its junction with the Snake is a little under 60,000 second-feet, carrying at least twelve times as much water as the Missouri river in Montana. Fortunately crops can be raised without irrigation nearly every year over a great part of these plains. Wheat is the staple crop, and when planted in the fall with the ground properly cultivated it yields heavily, the rains of winter and spring furnishing sufficient moisture to bring it to maturity. Wherever there is an available water supply, however, the farmers have begun to make use of it for irrigation in a small way, especially for watering such plants as are injured by the long summer droughts. Vegetables, fruit and shade trees, and the hay crops are thus irrigated wherever possible, and although the farmer can be successful by dependence upon the rainfall, yet it is slowly being recognized that the greatest prosperity can come only by a thorough employment of the available waters of the region.

The greater part of the irrigation of Washington is being done on the eastern edge of the Columbia plains or well within the foothills of the Cascade range in Kittitas and Yakima counties. Here the rainfall is probably less than it is farther to the east on the plains, but, on the other hand, the water supply is large and conveniently located. In short, there is no other portion of Washington which enjoys such facilities for the bringing out of water upon large bodies of fertile land. The rivers have not cut their channels into the late sedimentary deposits to a depth so great as to render it a matter of difficulty to divert water, and coming from high mountains they carry during the summer comparatively large amounts of water, thus rendering possible the construction of canals covering hundreds or thousands of acres of fertile land.

WATER SUPPLY AND PRECIPITATION.

Besides the rivers which flow from the eastern slopes of the Cascade range into the Columbia, the other streams important in irrigation are those flowing from the Blue mountains in the northeastern corner of Oregon, the principal of these forming the Wallawalla river. Northerly from this system of drainage and on the other side of the Snake are rivers and creeks flowing from the mountains of Idaho in a general westerly course and uniting in the Palouse or the Spokane river. These waters are comparatively little used, partly on account of the character of the topography, but mainly from the fact that irrigation is not considered essential. The floods in all these rivers occur early in the season, the rivers draining the lower foothills having their maximum discharge in March or April, while those from the more elevated mountains reach their highest point in May or June.

The Columbia river, as shown by the diagram of river heights published in the annual report of the chief of engineers, United States army, for 1889, page 2551, as a rule increases gradually in discharge through February, March, April, and May reaching its maximum in June. It then declines rapidly through July, August, September, and October, reaching its minimum in November or December. It is probable that the floods in the main river occur later in the season than those in the smaller tributaries from which water is taken for irrigation.

The average amount discharged by the Columbia river has not been ascertained, although a few measurements, mainly at low water, have been made. At Vancouver, just above the mouth of the Willamette, the low water discharge, as estimated by Major Thomas H. Hanbury, corps of engineers, was approximately 77,000 second-feet, while at a point above the Snake, as previously stated, the probable summer discharge has been placed at 60,000 second-feet. In comparison with this may be quoted the low water discharge of the Willamette, 15,000 second-feet, the highest known flood of this latter stream, that of February, 1890, reaching probably 400,000 second-feet.

There are comparatively few stations east of the Cascade range at which the rainfall has been measured for a number of years. At Pleasant Grove and Ellensburg, in Kittitas county, the results of measurements continued a little over 2 years, as shown by the records of the signal office, give an annual precipitation of a trifle less than 10 inches, and at Fort Simcoe, in Yakima county, about 50 miles southerly from Ellensburg, the rainfall for 2 years averaged 10.6 inches. At Kennewick, near the mouth of the Yakima river, the mean rainfall for 3 years was 6.6 inches, and about 25 miles south of this point, at Umatilla, Oregon, the mean rainfall for 5 years was 9.8 inches.

Farther to the east, at Wallawalla, on the river of the same name, the average rainfall for over 4 years was 16.2 inches, and at the fort south of the city the mean for 15 years was 17.0 inches. The elevation of Wallawalla is given at 930 feet above sea level.

Going easterly from the Columbia river toward the higher mountainous region of Idaho the amount of rainfall increases. For example, at Dayton, in Columbia county, where the elevation is approximately 1,600 feet, the average rainfall as obtained by 6 years' observation was 26.7 inches. At Pomeroy, in Garfield county, where the elevation is 1,900 feet, 2 years' observation of rainfall gave an average of 20.3 inches. At Colfax, in Whitman county, where the elevation is 1,974 feet, the average rainfall for 2 years was 26.1 inches.

This increase of rainfall from the plains region toward the mountains at the east is shown also in the case of the records at Fort Spokane and those at the city of Spokane. In the first instance, that at the fort, which is near the junction of the Spokane and Columbia rivers, at an elevation of 1,600 feet, the average rainfall for 7 years was 12.4 inches, while at Spokane, 50 miles farther east, and at an elevation of 1,910 feet, the mean annual rainfall for 9 years was 19.1 inches. Farther to the north, at Fort Colville, in Stevens county, the rainfall for 18 years averaged 17.2 inches. In comparison with the precipitation in eastern Washington may be noted that on the coast, where at one point the average has been upward of 110 inches per annum, the maximum being over 130 inches.

The distribution of precipitation by months has been obtained by compiling the records of the signal office relating to the principal rainfall stations of eastern Washington. The greatest amount of rain usually falls in January and the least in August, the amount increasing rapidly through the fall. Taking the mean of all the stations of eastern Washington at which observations have been continued for several years, it appears that in January there fell 16.0 per cent of the total precipitation of the year; in February, 13.0 per cent; in March, 7.4; April, 7.0; May, 7.0; June, 6.3; July, 3.7; August, 2.0; September, 5.0; October, 8.3; November, 9.3, and in December, 15.0 per cent. In December, January, and February 44.0 per cent of the total annual rainfall fell, while in July, August, and September only 10.7 per cent was precipitated.

Comparing the discharge of the rivers with the precipitation as regards distribution through the year, it is apparent that while the quantity of rain steadily diminishes from January until August the amount of water available, on the contrary, rapidly increases to May or June, and then falls off, the minimum river flow occurring a month or more after the time of least precipitation, both of these increasing toward winter.

The climate of the state has been discussed in publications prepared under the direction of the chief signal officer, one of these written in 1885 by Lieutenant Frank Green being a report on the interior wheat lands of Oregon and Washington. A second report by General A. W. Greely, on the climate of Oregon and Washington territory, printed in 1889, gives tables and diagrams illustrating the precipitation and temperature. Mention should also be made of the report by Lieutenant Thomas W. Symons of an examination of the upper Columbia river and the territory in its vicinity in September and October, 1881, and published in 1882. Briefly stated, it may be said that the climate of Washington is mild, the fluctuations of temperature being within relatively narrow limits. The winters are short and seldom severe except in the Big Bend country. The chief drawbacks are the long dry summer and the prevalence of winds, especially throughout the level country.

IRRIGATION DEVELOPMENT.

From what has already been stated it will be apparent that the relation of irrigation to agriculture in Washington is determined largely by convenience and the question of expense; that is to say, in eastern Washington agriculture is fairly successful in nearly every county without the artificial application of water, but wherever water can be obtained at moderate expense irrigation has been introduced, and the results obtained by this method of agriculture have demonstrated its value. On the other hand, where water can not be obtained the farmers claim that irrigation is unnecessary and seem to be content with the ordinary methods of farming, although it is apparent that many crops can not survive the scanty rainfall of summer combined with the effect of the almost ceaseless winds.

In most counties irrigation is still in the experimental stage, being used to tide over an occasional drought, and even in western Washington flooding of the lands is occasionally resorted to in order to increase the forage crops. For example, in Cowlitz and Skamania counties some of the smaller streams have been dammed in order to create artificial marshes, and even in Chehalis county the yield has been doubled by summer irrigation. One fact tending to retard the development of irrigation is the low selling value of cereals, together with the high rates of transportation. It obviously will not pay to irrigate lands to raise wheat when the farmers who are producing it in large quantities without irrigation can barely live.

There is a common saying among the inhabitants of eastern Washington that the bunch grass land, that is, the areas on which the rich, nutritious bunch grass grows, does not require irrigation. Wherever this flourishes wheat can be raised by proper cultivation. The bunch grass, which has the valuable property of self-curing or becoming a natural hay during the droughts of summer, is one of the most valuable of forage plants, and is so highly regarded that its name has become a synonym for anything valuable or prosperous. On the contrary, the lands on which the sagebrush grows, although having a rich soil, are too dry for cultivation without watering, and sagebrush land without water supply conveys ideas of worthlessness and poverty.

The methods of irrigation do not differ materially from those used elsewhere, the general practice being to flood the lands on which hay or cereals are raised, or to conduct the water through small furrows between rows of vegetables, corn, or other plants. Occasionally more systematic measures are used, as, for example, having the ground leveled and provided with low ridges of earth or checks by which the water is retained at a uniform depth over the inclosed area. The size of the space within the checks is regulated by the slope of the land, the more nearly level the larger the space. In one case the checks inclosed upward of 5 acres, and an irrigating stream was used sufficiently large to cover this ground in 2.5 hours. When one area is full, the water, unless the ground is very dry, is drawn off into the next area inclosed by checks, other water being run in at the same time by means of the small lateral ditches.

ARTESIAN WELLS.

Small artesian areas have been discovered near the eastern side of the plateau region, and also toward the western edge, not far from the foot of the Cascade mountains. Those on the east are at Pullman, in Whitman county, and near Latah, in Spokane county. At Pullman there are reported to be 8 wells from 70 to 180 feet in depth, 3 to 5 inches in diameter, and discharging on an average about 100 gallons per minute. The wells were put down for town supply, and none of the water has been used for irrigation, since there is usually an abundant rainfall. About 10 miles east of this locality are the flowing wells at Moscow, in Latah county, Idaho. In the Moxee valley, in Yakima county, two flowing wells are reported. Southeasterly from this point, near Pasco, in Franklin county, a well has been drilled to the depth of 527 feet without success. Attempts have been made in various parts of the state to obtain flowing water, but so far as can be ascertained they have been failures. At Tacoma the deep wells, although obtaining an ample supply of water, do not flow.

A geological reconnaissance by Israel C. Russell, of the United States Geological Survey, for the purpose of obtaining information as to the probable extent of artesian conditions in the counties of Yakima, Kittitas, and Douglas, confirmed the view that the geological structure of those counties is in general unfavorable to the hope of obtaining artesian waters. As described by him and by other writers, this country, together with the rest of central Washington, is underlaid by a thick sheet of lava, composed of many layers, above which are heavy deposits of clay, sand, and volcanic dust. These two great formations were originally horizontal, but now are broken by many lines of fracture, blocks being tilted in various directions, their edges forming mountain ranges. Thus it is evident that there can not be a broad artesian basin extending from the Cascade to the Rocky mountains.

In a very few localities the strata have been upturned in such a manner as to form small basins, but even these have sometimes been broken or cut by drainage channels, destroying what might otherwise have been conditions favorable for small artesian wells. The most notable case where the artesian character is found is in the Moxee valley, where successful wells have already been obtained. In the eastern part of the Yakima Indian reservation also, as Mr. Russell points out, the facts seem to show that flowing water may be obtained. In the remainder of the region examined he does not consider that farther expense in drilling wells is warranted.

CONDITION OF IRRIGATION IN EACH COUNTY.

NUMBER OF IRRIGATORS, AREA IRRIGATED, FARMS, AND CROPS, IN EACH COUNTY IN WASHINGTON IN 1889.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.	OWNERS OF FARMS. (a)		IRRIGATORS.		Area of counties in acres.	FARM AREA.		Cereals. (Acres.)	Alfalfa. (Acres.)	AREA IRRIGATED.			Average value of products per acre.
				Total number.	Per cent of population.	Per cent of farm owners.	Per cent of population.		Acres.	Per cent improved.			Per cent of area of county.	Per cent of total farm area.	Per cent of land owned by irrigators.	
Total	1,046	48,799	47	10,692	9.15	9.78	0.89	21,018,880	2,921,759	49.90	460,062	2,924	0.23	1.67	17.00	$17.00
Asotin	32	320	10	250	15.82	12.80	2.03	409,600	71,354	61.42	5,738	....	0.08	0.45	3.66	37.50
Columbia	15	139	9	722	10.76	2.08	0.22	552,960	225,525	64.09	53,831	171	0.03	0.06	4.31	36.80
Douglas	34	1,016	30	398	12.59	8.54	1.08	2,913.280	85,295	22.66	2,652	13	0.03	1.19	6.45	25.60
Franklin	3	44	15	30	4.31	10.00	0.43	796,160	7,095	19.56	....	9	0.01	0.62	4.86	8.50
Garfield	24	229	10	586	15.04	4.10	0.62	430,080	183,393	52.73	39,076	136	0.05	0.12	2.37	15.80
Kittitas	350	25,212	72	497	5.66	70.42	3.99	2,140,160	122,216	38.97	5,286	252	1.18	20.63	26.77	16.60
Klickitat	71	1,702	24	671	12.99	10.58	1.37	1,392,640	191,090	32.36	16,904	58	0.12	0.89	11.34	20.25
Lincoln	12	338	20	1,327	14.25	0.90	0.13	1,469,440	402,270	47.78	37,113	6	0.02	0.08	11.13	20.80
Spokane	3	80	27	2,132	5.69	0.14	0.01	1,075,200	441,662	34.71	46,681	1	0.01	0.02	6.46	....
Stevens	66	1,350	20	488	11.24	13.52	1.52	3,964,160	82,316	25.52	2,686	2	0.03	1.64	11.41	18.30
Wallawalla	121	2,809	23	850	6.95	14.24	0.99	829,440	344,222	77.98	108,168	1,161	0.34	0.82	7.97	36.90
Whitman	22	531	24	2,351	12.30	0.94	0.12	1,359,360	672,878	56.27	138.895	49	0.04	0.08	5.59	20.70
Yakima	293	15,129	52	390	8.81	75.13	6.62	3,686.400	92,443	31.60	3,052	1,006	0.41	16.37	19.03	17.80

a Includes owned and hired farms, assuming one farmer to each.

ADAMS COUNTY is a little east of the center of Washington, comprising a portion of the high plains or prairie partially surrounded by the great bend of the Columbia. No irrigation has been practiced in this county on account of the difficulty of obtaining water. The soil is rich, and in spite of the summer droughts retains sufficient moisture to enable wheat, rye, oats, and barley to mature. It is reported, however, that corn is not always successful.

The county has been settled but a few years, and the principal occupation is wheat raising. Difficulty is experienced in obtaining sufficient water for domestic purposes, and frequently it must be brought a distance of 4 or 5 miles. Wells are sunk usually to a depth of from 100 to 200 feet, occasionally without success. It is probable that in future a small amount of irrigation will be introduced by the use of the water of the Palouse river, which flows along the southeastern corner of the county, or by the storing of some of the flood waters of early spring.

ASOTIN COUNTY is in the southeastern corner of Washington, adjoining Wallowa county, Oregon, and separated from Nez Perces county, Idaho, by the Snake river. It comprises a portion of the high plateau country between the Blue mountains and the deep gorges of that stream. The Grande Ronde river enters the southern part and flows easterly into the Snake, and to the north of this are a number of smaller streams flowing from the mountains in the same general direction. All these streams are bordered by precipitous walls, rising in places to a height of several hundred and even a thousand feet.

The surface of the high divides between the streams is usually nearly level, and is covered by a rich soil, which, with an abundant rainfall, produces heavy crops. In 1885 there is reported to have been an unusual amount of precipitation. Large crops were raised and settlers flocked in. After that time there was a succession of years during which the rain apparently diminished in quantity. The crops were scanty, so much so that many of the settlers were compelled to seek homes elsewhere. In many localities the population in the census year is alleged to have been one-third less than it was 4 years before, and the production of wheat fell in one instance from 30 bushels per acre to about 12. The principal industry at present is stock raising, the cattle depending almost entirely upon the native bunch grass, which is about the only forage plant adapted to the dry climate.

A little irrigation is practiced on the bottom lands bordering the Snake river and Asotin creek, water being brought to the small level areas by ditches from side streams wherever practicable. Great difficulty is experienced in taking water from the river, as the topography is such that ditches can not readily be built. In a few cases pumps have been tried, and 3 pulsometers have been in use. The cost of a pumping plant capable of delivering 300 gallons per minute, or 0.66 of a second-foot, to a height of 60 feet is reported to be $1,000. The expense of operating this is $6 per day of 10 hours, this representing the cost of wood for fuel and the wages of one man. At the rate given a pump would deliver nearly one-half acre-foot of water per day, and thus an acre-foot would cost over $12. The water must evidently be used with very great care and a high duty obtained in order to make this profitable.

Another method of raising water to the top of the steep banks along the Snake is by means of waterwheels driven by the current. These are usually modifications of the ancient Egyptian noria, an undershot waterwheel carrying buckets upon its rim. A new device lately introduced consists of a wheel mounted upon a boat or raft securely fastened to the bank. This carries a tower 60 feet in height, to the top of which extends an endless belt carrying elevator scoops. The current drives the water wheel, and this in turn causes the scoops to carry water to the top of the tower, where it is discharged into a pipe leading down the tower, out to the shore, and up the bank nearly to the level of the top of the tower, where the pipe empties into a ditch.

COLUMBIA COUNTY is in southeastern Washington, extending in a narrow strip from the Snake river southward over the summits of the Blue mountains to the Oregon line. It is similar in topography and climate to Asotin county, from which it is separated by the narrow area of Garfield county. As in the case of those localities, wheat and other cereals and fruits are raised on the high rolling plateaus or hill lands, at elevations of from 1,500 to 3,000 feet. As a rule the higher grounds receive or retain more moisture than the lower, and crops are generally successful on them. In 1888, 1889, and 1890 the crops were lighter than usual, owing to the deficiency of rainfall.

The streams rising in the Blue mountains flow for a short distance northerly and then unite to form the Touchet river, whose general direction for a time is west, parallel with the Snake. After entering Wallawalla county it turns southward and empties into Wallawalla river, a tributary of the Snake. All these streams, like those of Asotin county, have cut deep gorges, rivaling that in which the Snake river flows. In the bottoms of these gorges are narrow strips of land, the soil of which requires irrigation in order to support plant life during the summer. With plenty of moisture the yield of fruit, alfalfa, and grasses for forage is very large, and farmers have been induced to attempt irrigation wherever practicable. The ditches are small, serving merely to irrigate a few acres of the bottom lands along the stream.

DOUGLAS COUNTY is a trifle east of the center of Washington and comprises a large part of the area known as the Big Bend country. It is bounded on the north, west, and partly on the south by the Columbia river, which, as before stated, describes roughly a great semicircle in this part of the state, cutting deeply into the high plain or plateau formed by the lava sheets which cover eastern Oregon and Washington. The surface of the county as a whole falls gradually from north to south, and is deeply cut by steep walled ravines, or coulees, as these are locally known. Of these Grand and Moses coulees are the most important, both traversing the northern half of the county diagonally from northeast to southwest. The former begins on the Columbia near the east line of the county and continues for about 55 miles toward Badger mountains. The walls of this chasm are, according to the report of Lieutenant Symons, about 350 feet high, and are nearly perpendicular, being broken down in only one place about half way of its length. At some places the coulee reaches a width of nearly 4 miles and in others becomes quite narrow. The nearly level bottom is about 1,000 feet above the Columbia river. The soil in many places is rich, but crops can not be produced without irrigation.

Moses coulee is from 12 to 15 miles west of Grand coulee and lies nearly parallel with it. Between the two is high land with rich soil, producing good crops wherever cultivated. The difficulty of procuring water for stock and domestic purposes has, however, retarded the settlement of this area. West of Moses coulee and between it and Columbia river is another area of high land, on which are most of the farms of the county. This is well adapted for agriculture in every respect save that of water supply. On these high grounds crops are less liable to be injured by frosts than on the lower lands, and there is probably a greater amount of moisture in the soil, so that wheat, oats, rye, and barley, and even some fruit trees, thrive and produce abundantly. The early settlers tried the low lands first from the supposed better facilities for water, but soon discovered the greater natural advantages of the higher grounds, both in possessing more moisture and in freedom from alkali. In many cases, however, they are compelled to bring water for long distances for household use during the summer. All the higher lands are farmed without irrigation, but on the low lands, both along the Columbia river and in the coulees, owing to the intense heat of summer nothing can be raised unless watered. As yet the county is sparsely settled, few farmers having been there for more than 5 years, and the water facilities have been so poor that irrigation has made little progress. There are few creeks in the county, and these, like the Columbia river, flow in deep gorges, so that their waters can be used only on the fringing bottom lands.

The southern half of the county is lower and less fertile, having almost the character of a desert. Apparently the droughts are too severe for the cultivation of cereals, and the pasturage is comparatively poor. There are low lands along the Columbia near and below Priest Rapids, the river having left its canyons, 2,000 feet or more in depth, and the banks being so low water can possibly be taken out for irrigation. There is already a project on foot to construct a canal heading in the mouth of the canyon and bringing out water upon the low lands near Priest Rapids and in the extreme southern end of Douglas county, the canals possibly extending into Franklin county. Such projects will require the expenditure of great capital, and it is still questionable whether the profits will be sufficiently great to induce any persons or corporations to undertake the work. Wherever these lands can be brought under irrigation, either by water from the river or from some spring or small stream, the yield of the various crops is enormous, and it has been found that all the grains and fruits reach a high degree of excellence. The county is described as largely a sagebrush desert of little present value and where water can not be had for irrigation In the vicinity of the thriving town of Waterville and along the border of Lincoln county the rainfall is usually sufficient for the production of a somewhat light crop of wheat. The rocks of the county are mainly basalt, having a thickness of about 2,000 feet. Beneath these lavas the rocks are much disturbed and deeply eroded, and the basin structure necessary to secure an artesian flow apparently does not exist.

FRANKLIN COUNTY is southeast of Douglas and south of Adams county, comprising that portion of the high plain of the Columbia north of and near the junction with the Snake river. It is in most respects similar in topography to the rest of the country within the great bend of the Columbia. As in the whole of this area, the cereals where raised are produced without irrigation, this latter method of agriculture being used only in the case of a few orchards on low ground. A project has been set on foot for irrigating some of the land along the Columbia by taking water from the Snake river a short distance above its mouth and bringing it by ditch to the vicinity of Pasco. It will be necessary to raise the water from the Snake river by machinery, and so far as can be ascertained the success of such a project is not yet assured.

GARFIELD COUNTY is in southeastern Washington, south of the Snake river, and between Asotin and Columbia counties. It consists principally of a high, deeply eroded plateau, around which the Snake flows almost in a semicircle, thus bounding it on the east and north. Toward the south the county extends in a narrow strip from 6 to 10 miles wide over the crest of the Blue mountains to the state line of Oregon. A number of small streams issue from this mountain area and flow outward to the Snake river. The principal of these are Alpowa, Deadman, Pataha, and Tokanon creeks, each of which flows in a deep gorge or canyon for the greater part of its course.

On the high and comparatively level lands wheat, rye, oats, and barley are raised successfully 3 or 4 years out of 5. Occasionally the drought proves too severe, and the farmers meet with losses and discouragements. Irrigation is carried on to a small extent on the narrow strips of land, from 100 to 300 feet wide, bordering the creeks just mentioned, and also on the small sandy bottoms or "bars" in the gorge of the Snake river. The success of peaches, plums, pears, apricots, grapes, and small fruits in these localities is wonderful, as the insect enemies of orchards and vineyards have not yet penetrated these regions. Water is diverted to the orchards and gardens in these places by means of small ditches from springs or from the stream itself. Along the Snake river a little water is raised to the sandy low lands by the use of pulsometers, thus irrigating a few valuable orchards.

There is little probability that water can ever be brought out upon the wheat lands, as the streams are from 100 to 1,500 feet below the general level. The soil of these lands usually retains moisture to a remarkable degree, and if there is a heavy fall of snow during the winter the farmers' success is assured. Water for domestic purposes is usually obtained from wells from 10 to 50 feet in depth, although in some localities the farmers have found it necessary to haul water for several miles. Irrigation is being practiced wherever water is accessible, and the present supply is nearly all utilized. The largest of the creeks mentioned, and probably the only one having a surplus of water, is the Tokanon, the others, particularly Deadman and Pataha, discharging in summer, it is said, only sufficient to supply water for stock and domestic purposes.

KITTITAS COUNTY is in the central part of Washington, east of the Cascade mountains, extending from the summits of that range in a general southeasterly direction to the Columbia river. It is bounded on the north by the Wenatchee river and on the south contains the head waters of the Yakima river, which flows southerly into Yakima county. Among the mountains at the head waters of these streams are numerous beautiful lakes several miles in length. These tend to equalize the flow of water in the streams and thus increase the summer discharge.

The principal agricultural area within this county is in the Kittitas valley, near the center of which is the town of Ellensburg. This valley is 10 miles or more in width and 18 miles long. It is bounded on the north and west by mountains containing deposits of valuable minerals and covered with timber. Within the valley little, if anything, can be raised without irrigation, as the precipitation during the summer months is very small and the winds which prevail tend to promote rapid evaporation. As pointed out by Mr. Russell, this valley is so situated in reference to the Yakima river and to the creeks coming from its mountain borders that nearly all of its lower land can be irrigated. There are excellent sites for storage reservoirs among the mountains and foothills, water to fill which can be obtained from the numerous creeks. The valley is on the edge of the high, somewhat humid region along the foot of the Cascade mountains, and on the uplands is a most excellent pasturage. To the east, however, the lands extending to the Columbia are more arid and the vegetation is scanty.

Water for irrigation is taken from the Yakima river or from small tributaries of that stream. In the case of the river itself there is a supply of water sufficient for all demands now made upon it. The smaller streams, however, do not furnish an abundance during the summer, but there is such scarcity that only a portion of the crops cultivated can be thoroughly irrigated, and it often becomes necessary to cut some of them for hay. Some of the farmers propose to increase the summer flow of the creeks by the construction of reservoirs in the mountains to hold a portion at least of the flood waters which now run to waste before the beginning of the irrigating season. As a result of the deficiency of the water supply controversies regarding water rights have already arisen, and expensive litigation has been entered upon by many of the farmers, who can ill afford this drain upon their resources. The greater part of the eastern half of the county is composed of broken lands and sagebrush plains, on which crops can rarely be raised without the artificial application of water. There is no visible means of supply for the greater part of this area, and it is difficult to obtain water even for domestic purposes. Near the junction of the Wenatchee with the Columbia a small amount of land is irrigated, principally by means of the waters of springs. It is probable that a portion at least of the lower part of the level lands here can be irrigated by water taken from the Wenatchee or the Pechastin, but the expense of constructing a ditch of the length required is beyond the means of the present inhabitants. Near Ellensburg two wells have been sunk to considerable depth in the hope of obtaining an artesian supply, but as yet without success. In the Kittitas valley the ordinary wells average about 30 feet in depth.

There are many small ditches in this county and a few of large size. Among the smaller ditches may be mentioned First Creek ditch, taking water out of a stream tributary to Swauk creek, which flows into the Yakima east of Teanaway river. This ditch is about 12 miles long and 6 feet wide, and cost probably $6,000 in all. It is owned by two irrigators, who divide the water equally. In 1889 about 600 acres were irrigated, about 500 acres being in wheat and the remainder in oats and vegetables. Gallaway ditch takes water from Wilson creek and carries it out in a southwesterly direction for about 8 miles. The average width is 5 feet. The ditch was constructed in 1877 by irrigators, who took advantage of an old channel of the stream which extends for a great part of this distance. In 1889, 400 acres were irrigated. Watt ditch takes water out of Manastash creek, which flows into the Yakima from the west side, nearly west of Ellensburg. The water is taken out upon the north side and carried a distance of 6 miles. The ditch is about 5 feet wide and cost probably $2,000. It is owned by private parties, who divide the water among themselves. The owners of this ditch, as is the case with many other irrigators, have been compelled to enter upon suits at law for the protection of their claims to the water. Bull ditch takes water from the Yakima river near Ellensburg and carries it out on the east side. The length of this ditch is 7 miles, the width about 7 feet, and the cost was $5,000. It is owned by farmers, who divide the water into tenths and distribute it according to the number of shares or tenths owned by each. In 1889 about 1,000 acres of meadow land and 500 acres of grain were irrigated. In the case of grain the water is turned into plow furrows from 60 to 100 feet apart, but the meadows are generally flooded, the flooding being repeated from two to four times each year.

The principal ditches of the county are those taking water from the Yakima river and carrying it out upon both sides in the vicinity of Ellensburg. The ditch on the east side of the river, owned by the Ellensburg Water

Company, is 25 miles long, 12 feet wide, and cost, for the 17 miles completed in 1890, $45,000. The owner of a share in this corporation is entitled to one-half miner's inch of water, this being considered sufficient to irrigate an acre. In 1889 about 2,000 acres were irrigated, the crops consisting of wheat, oats, barley, potatoes, and hay. The capacity of the ditch is reported to be 48 second-feet. The supply of water in the river is very large, but the ditch does not carry an amount sufficient for the demands made upon it. Above and north of this ditch is a large area of land which it is proposed to irrigate by the construction of a much larger canal, taking water from a point higher up the stream. The Westside irrigating canal is about 14 miles long and averages about 12 feet wide. It is estimated to cost when completed $30,000. At usual stages of the river there is no necessity of a dam for diverting the water. The corporation owning this ditch is composed of irrigators who use its water. Work was begun in June, 1889, and water was first used in 1890.

KLICKITAT COUNTY is in southern Washington, lying in a narrow strip along the Columbia river from the Cascade mountains eastward nearly to the mouth of the Snake river. A great part of the county, especially at the eastern end, consists of high plains similar to those on the opposite side of the river, in Umatilla and Morrow counties, Oregon. These plains are deeply cut by canyons, in which, in the springtime at least, small streams are to be found. The western end of the county is higher, being hilly or even mountainous in character. In nearly all parts of the county crops are raised without irrigation, but especially at the eastern end there are occasional failures, owing to a deficiency of rainfall. If there is a heavy fall of snow during the winter and this melts gradually, saturating the ground, the farmers can depend upon an abundant harvest, but if, on the contrary, the snowfall is light or melts rapidly before the ground thaws, the chances of success are reduced.

Irrigation is practiced on the low grounds along the Columbia river mainly for the purpose of raising fruit, and also in depressions known as swales. The water is obtained in nearly all instances from springs, a small amount being pumped by windmills. In the case of the swales the ground is naturally moist, and the irrigation processes, if they may be so called, consist in regulating the supply of water by means of dams, at one time allowing it to flow freely from the springs or at others draining it off when in excess. The principal crop raised in these localities is for forage. These areas, compared with those irrigated for gardens and orchards, are large and swell the total irrigated in the county. There are very few ditches for irrigation, and of these the Cameron ditch may be given as an example. It takes water from White Salmon river, carrying it out upon the west side for a distance of about 4 miles. The width of the ditch averages 6 feet and the cost was $3,000. It was begun in 1886 and used to a small extent in 1890. The water is diverted from the river at a point where there are two islands, part of the channel between them being obstructed by a log dam. Its course is mainly through land covered with a poor quality of pine timber, which must be cleared before the ground can be cultivated. The ditch has been built by private parties who have not yet been able to bring it to completion. The water supply is ample.

LINCOLN COUNTY is in eastern Washington, north of Adams county, and forms part of the great plains of the Columbia. It is bounded on the north by the Spokane and Columbia rivers. The drainage systems of the county consist of small creeks, a few of which flow northerly into the Spokane or the Columbia. The greater number, however, run in a general southwesterly course, finally uniting to form Crab creek, a stream flowing in a westerly direction through a series of lakes into Douglas county, where the waters finally disappear by evaporation from the surface of Alkali lake. These streams have cut deeply into the surface of the county and flow in canyons or gorges from 100 to 600 feet deep, or even more.

On the high rolling prairie lands of which the greater part of the county is composed nearly all crops of the temperate zone are successfully raised. The soil is very rich and in many years the yield is exceedingly large. The drought of 1889, so disastrous in other parts of the country, diminished the yield, but did not impoverish the farmers. There is usually a heavy fall of snow in winter, which, melting, saturates the ground to a great depth. Apparently the structure of the soil is such that as the dry season comes on some of this moisture returns toward the surface and reaches the roots of the plants. On the low lands along the streams, as, for example, in the narrow valley or gorge of the Columbia river and of Crab creek, crops usually require irrigation. The soil there is somewhat sandy, not retaining water for any great length of time. Springs issue from the walls of these gorges, usually at a depth of from 100 to 200 feet below the general level of the high prairie, and this water can be easily led out to irrigate the small patches of low ground.

From the character of the country and the fact that crops are successful without irrigation, it appears doubtful whether any large system of water supply will ever be introduced. The greater part of the water flows too far below the surface of the ground to be brought out upon the land, and the country is so rolling and broken by canyons that canal construction would be very expensive. The development of irrigation in a small way, however, will doubtless continue, as the benefits derived from this method of agriculture are such as in some places to warrant the expenditure of considerable sums for watering alfalfa, timothy, and other forage crops, as well as fruits and vegetables. At present a large part of the forage is made by cutting wheat and oats, since without irrigation alfalfa is not uniformly successful and frequently does not thrive through the droughts of summer. The water supply for domestic use is good. Wells usually reach water at a depth of from 10 to 30 feet, although in some places it is necessary to drill or bore to a depth of from 100 to 200 feet. So far as can be ascertained, none of this water rises and overflows.

Spokane county is in eastern Washington, adjoining Kootenai county, Idaho. The principal city, Spokane, is the commercial center for eastern Washington and northern Idaho, and the greater part of the business pertaining to the mining and manufacturing interests, as well as to agriculture, is transacted here. The surface of the country is hilly or consists of high rolling prairie lands with a rich soil, producing wonderful crops of cereals. The county is drained by the tributaries of the Spokane river, the outlet of Lake Cœur d'Alène. These streams have deeply eroded the surface and flow at a depth of from 100 to 400 feet below the level of the rolling prairie lands. Irrigation in this county is exceptional, since the rainfall may be considered as abundant for all crops. The only cases in which it is practiced are those in which a water supply was obtained with more than ordinary facility and utilized by men accustomed to that method of farming. Besides the three instances given, there are other cases in which water has been used in a small way for gardens and fruit trees, but these can scarcely be considered as systematic irrigation.

The majority of farmers in this county do not look upon irrigation as feasible or necessary, but there are a few who recognize that by means of an abundant water supply, even when the annual rainfall is large, the yield per acre can be greatly increased and a second or even a third cutting of forage plants obtained. There has been no year in which the crop failures have been particularly serious, although in 1889 the yield was greatly reduced. During the winter there is usually a heavy snowfall, which, melting, saturates the ground in spring, so that all the cereals except perhaps corn reach maturity, the size of the crop being in a rough way proportional to the depth of snow. The dry season begins usually about the first of June, after which there is little rain until late in the fall. There is an ample water supply for domestic purposes, and good wells are usually obtained, the depths being from 10 to 50 feet, or sometimes more. No flowing wells are reported.

Stevens county is in the northeastern corner of the state, bordering upon British Columbia on the north and Kootenai county, Idaho, on the east. From this latter county Clarke fork flows in a westerly direction into Stevens county, then continues northerly to a point 2 or 3 miles beyond the boundary of the United States, then it turns abruptly to the west again and empties into the Columbia, the junction of the two rivers being almost on the boundary line of the British possessions. The Columbia river, entering Washington, continues in a general southerly direction until it reaches the mouth of the Spokane river, which forms a portion of the southern boundary of Stevens county. It then continues westerly in its course around Douglas county.

The portion of Stevens county west of the Columbia river is included within the Colville Indian reservation. East of the river, however, are many farming areas, the greater part of which have been occupied for only a few years. This nearly triangular area, bounded on the west by the Columbia, on the east by Clarke fork, and on the south by the Spokane river, is known as the Colville region. It differs widely in many of its features from the country to the south, this difference being due largely to the absence of the lava sheets which underlie the greater part of the counties to the south, and give them their peculiar topography. The basaltic rocks do not extend north of the Spokane river, but in their place are rocks related to the granites, and instead of the steep cliffs bordering the streams, as in the case of the basaltic areas to the south, are sandy terraces rising gradually from the river bottoms.

A large amount of detailed information concerning this area is made available by the contoured maps and descriptions of the Colville country, prepared by the northern transcontinental survey and published in 1883. As shown by the agricultural map, the Colville valley, with its rich alluvial soil, extends in a general northerly direction through about the center of this area, being continued on the north by Echo valley to the terrace lands of the Columbia, and on the south to the Spokane river by the sandy plateau and terrace lands of Chamokane creek. Throughout this region, especially on the bottom lands, agriculture is generally successful without the aid of irrigation, although many of the farmers have found it of benefit to divert water from the small streams for gardens and trees upon sandy soils. As a general statement it may be said that grasses, fruit and shade trees, as well as corn and vegetables, grow better if irrigated during the long drought of summer. On the bottom lands along the Colville river redtop and timothy hay are the principal products, wheat and oats being raised on the benches and depending for their moisture upon the rains.

The Colville valley is bounded by mountainous areas, the surface of which is too broken for agriculture. To the east, along Clarke fork, in the vicinity of Calispell and southeasterly from that point, are broad bottom lands usually overflowed each year by the spring freshets, so that, as in the case of other valleys along this stream, drainage is sometimes more necessary than irrigation. If the annual overflow does not occur, however, and the hay lands along the river and creek bottoms are not thoroughly wet, the crop is greatly reduced and is sometimes hardly worth cutting. On the western edge of the Colville region, along the banks of the Columbia, is a succession of low terraces, with rich though sandy soil. Here irrigation is generally necessary, although crops have been raised without it. Water is taken from the small creeks which flow into the Columbia and is used for gardens, orchards, and hay lands. It is possible that a canal may be taken out of the Columbia at some time to cover a portion of these terraced lands.

There are very few ditches of any importance in the county, the greater number being less than a mile in length and conducting water from the little creeks, which are found at intervals of from 8 to 10 miles throughout this mountainous area. One hindrance to the greater development of irrigation is that many of the settlers are still upon unsurveyed land, so that they do not know whether they are making improvements upon land that will eventually be their own or upon land the title to which will be obtained by some other person.

WALLAWALLA COUNTY is in southeastern Washington, south of the Snake river and east of the Columbia, extending from these streams along the Oregon state line nearly to the summits of the Blue mountains. The Touchet river flows west and south nearly through the center of the county, entering the Wallawalla river, whose course is westerly along the southern boundary. The streams flow in deep gorges hundreds of feet below the general level of the uplands. The principal occupation of the people of this county is wheat raising, large crops being produced each year, and especially when the snowfall of the preceding winter is heavy. It is customary to summer fallow the land every third year, and thus, on an average, two-thirds of the farm land is in crop each season. Occasionally a small amount of corn is raised on this summer fallowed land. Beside wheat some barley, oats, and rye are produced, and occasionally potatoes and other vegetables, although in many parts of the county there is not sufficient moisture to make the yield of the latter profitable.

In the northern end of the county, between the Snake and Touchet rivers and in a general way parallel to them, is the high plateau known as Eureka flat. This is from 30 to 40 miles long and about 6 miles wide. The soil is rich, and enormous quantities of wheat are produced each year. The water supply for this area is, however, greatly deficient. The farmers are compelled to procure water for summer use by saving in cisterns the water from melted snow, by purchasing from the railroad company or by hauling from streams at distances of from 5 to 10 miles by means of wooden tanks mounted on stout wagons. It is reported that in 1889 the water filling a 500-gallon tank cost $4 and that the same quantity in 1890 cost $2. One farmer writes that in one year it cost him $50 for water for household use and to supply 4 horses. Water obtained from the railroad cost $12.50 for 2,500 gallons, with an additional expense of from $5 to $8 to bring it from the railroad station.

Efforts have been made to obtain water by drilling, but it has been found very difficult to penetrate the hard basaltic rock. Small pieces are easily dislodged by the drill and wedge it firmly, so that it becomes very difficult and in some cases impossible to withdraw the drilling tools. Wells have been put down to depths of from 300 to 400 feet without obtaining water, the drill having finally stuck fast. In some parts of the county less difficulty is experienced in obtaining water. One well is reported to be 130 feet deep and with 40 feet of water. Irrigation is carried on along the Snake, Columbia, and Wallawalla rivers, and to a less extent along Touchet river, wherever water can be brought out by small ditches, water wheels, or force pumps. Gardens and fruit trees cultivated in this manner prove highly profitable, as the wheat growers on the higher lands raise very few vegetables or fruits, and thus there is little competition and a large demand for this class of produce.

WHITMAN COUNTY is on the eastern edge of Washington, south of Spokane county and north of the Snake river, and includes the greater part of the high rolling lands traversed by the Palouse river. This stream and its tributaries rise in the mountains of northern Idaho and flow westerly into Whitman county, where the river turns toward the south, and forming the southwestern border of the county flows into the Snake. The surface of the country as a whole falls from the mountainous region on the east, sloping in a general way westerly out toward the great plains of the Columbia. It is broken, however, by innumerable hills, rising gently from heights of from 100 to several hundred feet above the valleys. The drainage channels have been deeply carved into this high rolling country, and the streams for the greater part of their course are in deep gorges.

The eastern half of the county has an abundant rainfall, and the yield of crops can rarely be surpassed by that of any other area. The western half, being out toward the plains of the Columbia, is somewhat dryer, and seasons of deficient rainfall prove more serious. Losses are generally prevented by thorough cultivation. The soil of the county is very rich, consisting largely of a deep black loam, and the yield of most of the cereals is extraordinarily great. No irrigation is required, as there is usually ample moisture to mature the wheat, oats, barley, and other crops. Fruit and shade trees thrive on the higher lands, and rarely is there serious loss through drought.

On the low ground along the Snake river are a few irrigated areas. Here the soil is sandy, and the temperature is higher than on the upper lands, so that crops and fruit trees require the application of water during the summer. These strips of low land are locally known as "bars" or "flats". They are not continuous, but are separated from each other by rocky points which extend down to the river's edge. This is sometimes known as the fruit area of the county, as the greater part of the orchards are to be found here. On the higher grounds some apples and other fruits are produced, and their owners claim that the flavor is better than in the case of fruit from irrigated orchards, but on this point there is difference of opinion.

Water is usually obtained by sinking wells to a depth of from 10 to 50 feet, although in some cases it is necessary to go deeper. At Pullman there are reported to be 8 flowing wells of a depth of from 70 to 180 feet. The cost of these wells ranged from $3 to $4 per foot. The wells are from 3 to 6 inches in diameter, and are reported to deliver 800 gallons per minute. There are also 2 flowing wells at Moscow, in Latah county, Idaho, about 10 miles east of Pullman. These wells supply water mainly for domestic purposes, none being used for irrigation.

YAKIMA COUNTY is south of Kittitas and north of Klickitat, these three counties extending from the summits of the Cascade mountains eastward to the Columbia river. The Yakima river rises in the county to the north and flows in a general southeasterly course into Yakima county, where it receives numerous tributaries from the mountains on the west. The agricultural settlements are along these streams, the most prosperous being at places where water can be taken out to cover large areas of the fertile bench and valley lands. As a general rule nothing can be raised without irrigation, although there are a few favored spots where wheat has been successful without the artificial application of water. In the eastern end of the county, toward the plains of the Columbia, there are localities where farming without irrigation is attempted, but the yield is so small as barely to repay the efforts of the cultivator.

The topography of this county is shown by maps made by the northern transcontinental survey in 1883. The area surveyed includes the Kittitas valley and the southern portion of Kittitas county, as well as the greater part of Yakima county. Besides the topography, which is shown by contoured lines, the forest areas have been outlined and the soils studied, the results in each case being shown by colored maps. This area is characterized by ridges running in a general easterly and westerly direction, many of them being cut by the Yakima river. Between these are fertile valleys, the soil of which yields large crops wherever water can be brought upon it.

The first of these valleys is the Kittitas valley, previously mentioned in the description of the county of that name. After leaving this area the river passes through the Beavertail and Umptanum ridges, having cut a picturesque canyon about 15 miles long and from 1,000 to 1,800 feet in depth. It then crosses a valley extending east and west, the portion on the west or right bank of the river being known as the Wenas or Naches valley and on the east the Selah valley. South of these is another ridge of upturned lava known as the Selah ridge, separating these valleys from a similar long, narrow basin on the south. The most notable part of this basin is the Moxee valley, on the east side of the Yakima river. The part of the basin to the west of the river, in which Yakima and North Yakima are situated, is known as Atanam valley. The total length of this basin or valley is from 75 to 80 miles and the width is not greater than 5 or 6 miles. South of the valley the river again cuts through a lava uplift, the Yakima ridge, and enters the large Yakima valley, which extends down toward the Columbia, being 45 miles or more in length and from 10 to 15 miles in width. The Yakima river leaves the valley of that name through a narrow pass and enters the low lands along the Columbia, flowing through these to join that stream. These lands are at an elevation of 100 feet or even less above the Columbia, rising toward the west. They extend from near Wallula for about 50 miles upstream, broadening to a width of 20 miles at points above the mouth of the Yakima river.

The greater portion of the center of the county west of the Yakima river is occupied by the Indian reservation, which thus includes a large part of Yakima prairie. Northeast of this prairie are rolling hills and plateaus, generally covered with nutritious bunch grass valuable for stock raising. The soil is rich, and with an abundant rainfall good crops could be raised. In some localities large areas of government land have been taken up, and settlers have raised from 10 to 20 bushels of wheat to the acre. The majority, however, have not been able to secure a crop, and many homesteads have been abandoned.

The Yakima river and its principal tributary, the Naches, rise among the high peaks of the Cascade range and thus have a large perennial supply of water. Other streams of the county, as, for example, Wenas creek and Atanam river, derive most of their water from spurs of the range, on which, the altitude being less, the snows melt earlier in the spring, giving a diminished summer flow. Along streams of this latter character the area under cultivation has already exceeded the amount which can be irrigated by present means, and as a result there is scarcity of water during the latter part of the crop season, especially among the irrigators on the lower portion of the streams. It is evident that water storage must be utilized to save some of the surplus water of early spring, which usually comes in a flood of duration so short that the irrigators have barely time to give their lands one thorough watering. In many of the streams there are often two decided floods, the earlier resulting from the melting of the snows on the lower foothills, following a warm wind or rain. Later in the spring the snows on the higher mountains begin to melt, sometimes keeping up the height of the water, and at other times giving rise to a second well marked flood. The creeks which do not receive this second supply shrink during June, so that by the first of July there is hardly enough water for gardens and stock. Some of the lower grounds along the creeks receive sufficient moisture by seepage from the streams or from the ditches on the benches to raise crops without the application of water to the surface, but the higher lands must be irrigated, except perhaps in the case of those at an elevation of 2,000 feet or more above sea level.

A large part of the irrigation in this county is carried on by means of ditches built by the farmers, either individually or in partnership. These men, as a rule, have had little money to invest in the development of the water supply, but they have contributed freely of their labor. The short crops of the census year diminished their resources, so that generally they could not unaided undertake larger enterprises, such as the building of long canal systems. In 1889 and the following years outside capital was attracted by the apparent opportunities for profitable investment in works of this character, and corporations began to increase in number. The largest canal thus built is that known as the Sunnyside, built by the Northern Pacific, Yakima, and Kittitas Irrigation

Company, covering lands on the east or northeast side of Yakima river, near Topinish and the new town of Zillah. This canal is on an average 30 feet wide, 6 feet deep, and has a total length of 60 miles. It covers about 240,000 acres of good agricultural lands. Farther down the river, in the vicinity of Prosser and Kiona, are the works of the Columbia and Yakima Irrigation Company and also of the Yakima Irrigating and Improvement Company, all taking water from Yakima river and carrying it to lands in the valleys near the mouth of this stream or northerly along the west side of Columbia river.

In many of the valleys previously mentioned much of the land lies at an elevation too great to be covered by canals from the streams, or if sufficiently low the expense of construction is prohibitory. In the eastern part of the county it is exceedingly difficult to obtain water sufficient even for domestic purposes, much less for irrigation, it being necessary to haul the water for long distances. Great attention, therefore, has been given to the possibilities of obtaining artesian flows. The first attempt to discover artesian water was made at the expense of the state, the well being located on Horse Heaven plateau in section 36, township 8 north, range 26 east. In this excellent grazing region the need of water is very great. This well is 630 feet in depth and is reported to have cost $3,400, this somewhat large amount being due to the fact that the drill penetrated several hundred feet of basalt, progress through which was extremely slow. Water was struck at a depth of 225 feet, but it did not rise to a higher level. The structure of this area, as described by Mr. Russell, is that of a great block uptilted toward the north, the strata becoming almost horizontal 10 miles to the south of the edge of the fracture and still farther to the south broken again. There is thus nothing of the basin structure essential to the existence of artesian wells.

The successful wells so far discovered are in the Moxee valley, where the somewhat rare combination of conditions resulting in artesian flows has been found to exist. Deep borings have been made by the Yakima Land Company, the Washington Irrigation Company, and others. Well No. 1, of the Yakima Land Company, was the first flowing well in that part of the state. It is located on section 3, township 12 north, range 20 east. The elevation of the ground at the mouth of the well is approximately 1,166 feet above sea level, and when other wells are closed the water rises 26 feet higher, or to an elevation of 1,192 feet. The well is 6 inches in diameter, 314 feet deep, and discharges at the rate of about 0.6 second-feet, the water having a temperature of 75 degrees fahrenheit. Well No. 2 is located on section 4 of the same township and range, is 8 inches in diameter, and 618 feet deep. The elevation of the ground at the well is 1,206 feet and the water rises in the hole to within 12 feet of the top, or to an elevation of 1,194 feet, or practically the same height as in the case of well No. 1. Well No. 3 is 300 feet from No. 1 and in the same section. The top of the well is at an elevation of 1,154 feet, and when well No. 1 is closed the water rises 35 feet above ground, or to an altitude of 1,189 feet above sea level. Well No. 4, in section 4 of the same township and range, is 583 feet in depth. The top of the well is at 1,266 feet, and water rises only to within 80 feet of the surface, or to an altitude of 1,186 feet. Well No. 5 was drilled in section 25, township 13 north, range 19 east, but was not completed at the time of Mr. Russell's report.

A comparison of the results obtained in each of these wells shows that when not flowing the water would stand at approximately the same level in all, namely, at an altitude above the sea of 1,190 feet, this, as pointed out by Mr. Russell, being the limiting height for this part of the basin. The other conditions, however, which determine the area of a basin and the probability of permanence of supply, are somewhat complicated. Well No. 1, of the Washington Irrigation Company, is located in section 31, township 13 north, range 20 east. The elevation of the surface is approximately 1,085 feet. The discharge is estimated to be 0.3 second-feet. The water has a temperature of 73 degrees fahrenheit. West of North Yakima, in what is known as Wide Hollow, are two wells, one having a depth of 256 feet. The elevation of the top of the other well is 1,125 feet and its total depth is about 530 feet. Neither of these flows.

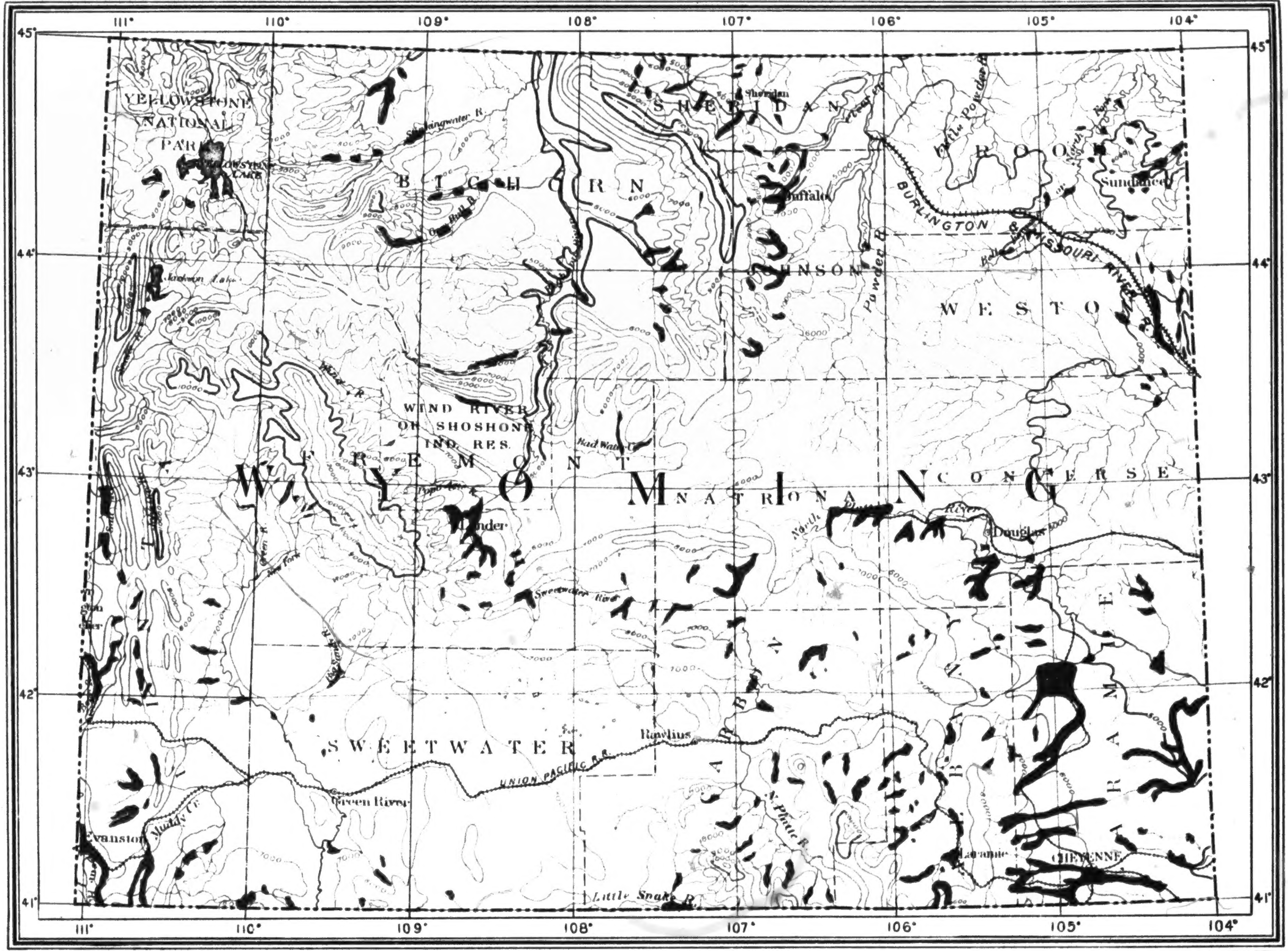
WYOMING.

Total population (average per square mile, 0.62)		60,705
Number of owners of farms (5.15 per cent of population)		3,125
Number of irrigators (61.34 per cent of farm owners and 3.16 per cent of population)		1,917
Area of state, land surface (97,575 square miles)	acres	62,448,000
Area irrigated in census year	do	229,676
Area of all farms (26.05 per cent improved)	do	1,830,432
Cereals raised in census year, including 20 acres in buckwheat and 141 acres in rye	do	21,815
Barley (average production, 24.20 bushels per acre)	do	486
Corn (average production, 12.73 bushels per acre)	do	1,977
Oats (average production, 26.60 bushels per acre)	do	14,607
Wheat (average production, 16.24 bushels per acre)	do	4,584
Alfalfa	do	5,270
Total value of all farms, including land, fences, and buildings		$14,460,880
Estimated total value of the farms irrigated in whole or in part		$7,212,000
Estimated value of all farm productions (sold, consumed, or on hand) for 1889		$2,241,590
Estimated value of productions (as above) from farms irrigated in whole or in part		$1,895,000
Average size of irrigated farms	acres	120
Average size of irrigated farms of 160 acres and upward	do	494
Per cent of acreage of irrigated farms of 160 acres and upward to total acreage irrigated		65.18
Average size of irrigated farms under 160 acres	acres	50
Average first cost of water right per acre		$3.62
Average annual cost of water per acre		$0.44
Average first cost per acre of preparation for cultivation		$8.23
Average value of irrigated land, including buildings, etc., in June, 1890, per acre		$31.40
Average annual value of products per acre in 1889		$8.25

GENERAL DESCRIPTION.

In number of irrigators in the census year Wyoming stood above Arizona, Washington, and Nevada and in area irrigated was near the middle of the list of the 11 states and territories. As a consequence of the large acreage reported as under irrigation, the average size of irrigated farms was necessarily large, 120 acres, in this respect standing second only to Nevada. The principal product on the irrigated land being hay, and much of this from native grasses, the average value of products was very low, $8.25 per acre. Taking out the large irrigated farms, that is, those of 160 acres and upward, there remained less than 35 per cent of the land in what may be called small irrigated farms, these averaging 50 acres in size. Thus, in respect to proportion of large holdings, this state was far above the average, subdivision of large holdings not having been carried on to a very perceptible degree. The reports as to the first cost of water rights per acre and the average annual cost indicated that these were lower than in any other part of the country, this being apparently due to the many instances where small ditches were constructed by farmers who placed little value on their own labor.

Wyoming lies principally within the northwesterly portion of the Great Plains. The continental divide crosses the state diagonally, running in a general northwest and southeast direction, the southwestern corner of the state containing the headwaters of streams flowing into the great interior basin or southward to the Colorado river. From the continental divide the land as a whole falls gradually to the north and east toward the Yellowstone and the Missouri, the rivers flowing either northward into the Yellowstone or eastward down the slope of the Great Plains. This gentle slope toward the Missouri is interrupted in several instances by mountain ranges, whose course is in general slightly west of north and east of south, the most conspicuous examples being the Bighorn range in the northern part of the state and the Medicine Bow and Laramie ranges in the southern part. These, with the Wind river and Absaroka ranges, induce most of the precipitation of the state, and to their presence is due the greater part of the agricultural possibilities of Wyoming, for from these mountains come the streams most important to agriculture. The continental divide crossing this state is not in all places well marked; in fact, it may be said that the plains sweep over the divide into the head waters of the Colorado. This lofty plain, where unbroken by mountains, does not receive sufficient water to render agriculture possible on a large scale, even if the climate was sufficiently temperate for the ordinary crops.


WYOMING
YELLOWSTONE NATIONAL PARK
Yellowstone Lake
Jackson Lake
BIG HORN
SHERIDAN
Sheridan
JOHNSON
Buffalo
CROOK
Sundance
WESTON
CONVERSE
Douglas
FREMONT
WIND RIVER OR SHOSHONE IND. RES.
Lander
NATRONA
CARBON
Rawlins
ALBANY
Laramie
LARAMIE
CHEYENNE
SWEETWATER
Green River
UINTA
Evanston
BURLINGTON & MISSOURI RIVER R.R.
UNION PACIFIC R.R.
Stinkingwater R.
Grey Bull R.
Wind R.
Powder R.
Little Powder R.
Belle Fourche R.
North Platte River
N. Platte R.
Sweetwater River
Bad Water Cr.
Popo Agie R.
Green R.
New Fork
Big Sandy R.
Little Snake R.
Muddy Cr.
Clear Cr.
111°
110°
109°
108°
107°
106°
105°
104°
45°
44°
43°
42°
41°
5000
6000
7000
8000
9000
10000
IRRIGATED

MAP OF WYOMING SHOWING AREAS IRRIGATED IN 1889.

The agricultural land of Wyoming as a whole lies at the greatest altitude of that of any state in the Union, nearly one-half of the total area being above 6,500 feet. The character of the agriculture and that of the products are governed by this fact, and, as is well known, the pastoral industries lead in importance, areas devoted to these practically embracing the greater part of the state. Agriculture proper, the tilling of the soil, is making rapid progress in some portions, especially at the lower altitudes, as, for example, in Johnson and Sheridan counties, along the base of the Bighorn range in the northern part of the state, and also in the more thickly settled parts adjacent to Colorado on the southeast. In the northern counties in the valleys of the Powder, Tongue, and Bighorn rivers, where the altitude is from about 3,500 feet upward, and also to the southeast in Laramie county, nearly all kinds of fruit and vegetables of the temperate region reach maturity, and in all parts of the state grass and the hardier grains flourish, many of the higher plains being too cold for corn. Nothing, however, can be grown without irrigation, with the exception perhaps of a scanty crop in some spot occasionally favored with an unusual summer's rain. No dependence can be placed upon nonirrigated crops and the yield at best hardly repays the trouble. As a result, with a vast area of arable land agricultural development is restrained by the uncertainty of securing water. Irrigation is still in its infancy, and there are few works of notable size, the only exceptions perhaps being in the case of canals in Albany and Laramie counties. There are numerous small ditches leading from the streams out upon the lowest bottom lands, where in most instances a few well located high line canals would serve more land with greater economy. Many of the earlier canals were so faulty in construction and in alignment that the cost of repair has been large, and lack of economy of water has ensued. There is need of systematizing the water diversions from each stream.

WATER SUPPLY.

The water supply of the state as a whole is remarkably good, since there is a large proportion of perennial streams of notable size. The valleys along the Bighorn river and also those to the east of the range of that name receive a large amount of water from the great mountain ranges bordering them. Agricultural development, especially in the north, has been retarded by the lack of transportation facilities, the only railroad until of late years being that crossing the southern part of the state. On the east the tributaries of the Platte have been used nearly to their full capacity for irrigation, the water in the Platte itself being employed to a less extent on account of small slope of the stream and the consequent expense of headworks, irrigation from the tributaries being cheaper. There are many canals, especially along the larger rivers, which receive water only during times of flood. These so-called high water canals are very cheaply built, the headworks, if any, being of temporary character. Water is by this means turned out upon grazing lands, only one thorough watering during the year being secured. In such cases the use of the term "irrigated land" is open to criticism, especially when used in comparisons of statistics from lands where irrigation for grazing is impracticable.

There has been the same complaint in Wyoming as in other states, that with increase of population and pushing of settlement toward the head waters the water is used to a greater extent in the upper valleys, where irrigation is cheaper, but where the climate is less favorable for agriculture, and that by this increased use of the small tributaries the supply of water is diminished in the main stream below to the detriment of prior appropriators. The available supply must be increased by utilizing all the facilities for conserving water, and at the present time steps are being taken in this direction. Some small storage basins are used, but they are insignificant as compared with the untouched facilities. As the matter now stands, the amount of water in the streams depends directly upon the depth of snowfall in the mountains, the rain having comparatively little influence upon the amount available for irrigation. In fact, the irrigator cares little about the quantity or distribution of the rain, his chief concern being the amount of snow in the mountains and the distribution of temperature through the spring and summer, an early warm spring causing the snow to disappear rapidly, while comparatively cool weather in the mountains allows the snow to remain later and keep up the discharge of the streams at the critical time.

The average distribution of the water in the streams in and adjoining Wyoming throughout the year is shown by the following percentages of discharge for each month. As given in the results obtained by the United States Geological Survey, in January the discharge was 3.5 per cent of that of the entire year; February, 4.0; March, 5.0; April, 9.0; May, 25.0; June, 23.0; July, 12.0; August, 5.0; September, 3.5; October, 3.4; November, 3.3; December, 3.3. That is to say, in May, taking the averages of a large number of streams, one-fourth of the amount for the entire year was discharged, or five times the amount discharged in August and over twice that discharged in July. Taking May and June together, nearly one-half the total for the whole year was discharged, or four times that of July, the month in which the crops are in full growth. It is self-evident that by saving a part of this water so plentiful in May and June until July, and especially until August, a far greater acreage can be given a second or third watering. It would be necessary to hold the greater part of this water a very short time, for the culmination of the flood occurs in the latter part of May or the first part of June, while the greatest need is in the latter part of July and in August. The amount of water flowing to waste in winter, although relatively of small significance, would aid in swelling the amount available for storage.

WATER CONTROL.

The legislation recently enacted, approved December 22, 1890, promises a speedy solution of many of the troubles besetting the irrigator, and its practical operations are being watched by the people throughout the arid lands. In preparing these laws advantage has been taken of the experience of other states, and much that is best has been incorporated from the laws of other irrigating countries, especially those of the state of Colorado, where certain of the provisions have been put to practical test. The law is unique in this, that the state does not necessarily wait for controversies and losses to arise, but of its own motion steps in and ascertains how much water is available for irrigation, who are the claimants to this water, and then, knowing these fundamental facts, it gives the use of the water to the proper persons, and employs its own agents to see that the distribution is made.

Under late legislation the state engineer has charge of all the details of water distribution throughout the state, and he, with four superintendents, one from each water division, constitutes a board of control to determine all questions that may arise. Under each superintendent are a number of water commissioners, one for each minor district, whose duties are to enforce the proper distribution and carry out the local regulations. The state engineer is to make measurements of the amount of water in the stream, to determine the most suitable location of irrigation works and lands to be irrigated, and, further, to examine reservoir sites and publish estimates of the cost of storage and distributing systems. The superintendent in each division is to make suitable regulations to secure the fair distribution of water, and by the aid of the water commissioners to keep a record of the amount of water needed, available, or wasted, and if the water is not justly distributed he must enforce division according to his list of priorities. The board of control, of which the state engineer is the head, can appoint a date upon which to examine into the rights of all persons using water from any streams, and knowing the amount of water available, as determined by the state engineer, as well as the area of land irrigated or susceptible of irrigation, it can then make an order determining the rights of each person, giving to no appropriator more water than he can put to beneficial use, the maximum limitation being set at 1 second-foot for 70 acres. Each person is then given a certificate showing the order of priority, the amount of water to which he is entitled, and the number of acres upon which the water is to be used.

No future appropriation of water can be made until the board of control is satisfied that there is unappropriated water, and that its use will not be detrimental to public interests. The second-foot is made the legal unit, thus avoiding the trouble arising from the use of that indefinite quantity, the miner's inch. Each appropriator must maintain head gates by which the water can be turned on or off, and also a flume or weir for measuring the water in his ditch. All dams over 5 feet in height for raising and diverting water must be approved by the state engineer, thus insuring an official inspection of such structures.

From the above abstract it is apparent that the state engineer and board of control hold the most important offices in the state, so far as agricultural interests are concerned, and by a wise and skillful exercise of the functions intrusted to them they can bring about a thorough development of the agricultural resources of the state. With the exception of a part of the head waters of the North Platte and Bear, all the streams rise within the state and are under the control of state officers without hindrance from outside parties. Apparently only such water as Wyoming can not use need be discharged across her borders to Nebraska, the Dakotas, Montana, Idaho, and Utah. She holds the key to the storehouse of agricultural wealth.

WELLS.

In Wyoming a great number of wells have been drilled to depths of from 100 to 1,000 feet or more in the search for petroleum. Usually these pass through strata carrying large amounts of salt water, which, if allowed to do so, rises and overflows at the surface. This water, so far as ordinary uses are concerned, is worthless on account of the large amount of mineral matter which it contains. Occasionally the deep borings have struck fresh water, but these cases are rare and the amount delivered is usually small. There is reported to be a flowing well at Cheyenne; also others south of Laramie, in Albany county, and in the vicinity of Sheridan, in Sheridan county. At this latter locality are two wells, one of which, 500 feet in depth, delivers less than a gallon a minute, and in the other, 452 feet, the water rises only to within 6 feet of the surface.

CONDITION OF IRRIGATION IN EACH COUNTY.

NUMBER OF IRRIGATORS, AREA IRRIGATED, FARMS, AND CROPS IN EACH COUNTY IN WYOMING IN 1889.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.	OWNERS OF FARMS. (a)		IRRIGATORS.		Area of counties in acres.	FARM AREA.		Cereals. (Acres.)	Alfalfa. (Acres.)	AREA IRRIGATED.			Average value of products per acre.
				Total number.	Per cent of population.	Per cent of farm owners.	Per cent of population.		Acres.	Per cent improved.			Per cent of area of county.	Per cent of total farm area.	Per cent of land owned by irrigators.	
Total	1,917	229,676	120	3,125	5.15	61.34	3.16	62,448,000	1,830,432	26.05	21,815	5,270	0.37	12.55	15.24	$8.25
Albany	125	34,522	276	140	1.58	89.29	1.41	2,880,000	214,955	32.19	408	216	1.20	16.06	16.06	9.30
Carbon	272	39,869	147	295	4.30	92.20	3.97	4,992,000	133,241	60.22	1,473	30	0.80	29.92	30.72	6.83
Converse	72	6,890	96	144	5.26	50.00	2.63	4,224,000	45,460	23.91	628	112	0.16	15.16	21.81	6.72
Crook	59	3,027	51	540	23.10	10.93	2.52	3,360,000	127,245	18.88	3,730	46	0.09	2.38	15.62	10.15
Fremont (b)	217	15,512	71	366	14.86	59.29	8.81	15,526,400	96,273	32.54	3,198	1,233	0.10	16.11	23.87	12.25
Johnson	278	28,106	101	307	13.03	90.55	11.79	2,560,000	123,594	46.94	3,576	779	1.10	22.74	24.62	7.97
Laramie	208	33,853	163	405	2.41	51.36	1.24	4,496,000	774,161	15.07	2,104	652	0.75	4.37	5.09	12.44
Natrona	43	5,547	129	165	15.08	26.06	3.93	3,504,000	48,197	28.32	52	135	0.16	11.51	18.46	(c)
Sheridan	294	29,723	101	356	18.05	82.58	14.91	1,776,000	124,749	27.48	5,983	1,144	1.67	23.83	27.14	6.94
Sweetwater	20	1,362	68	23	0.47	86.96	0.40	6,547,200	4,757	30.82	26	23	0.02	28.63	34.39	(c)
Uinta	324	30,918	95	360	4.57	90.00	4.11	9,491,200	130,330	27.77	597	900	0.33	23.72	25.64	6.09
Weston	5	348	70	24	0.99	20.83	0.21	3,091,200	7,470	12.02	40	....	0.01	4.66	11.44	7.59

a Includes owned and hired farms, assuming one farmer to each.

b Including Bighorn county.

c Returns not complete.

ALBANY COUNTY is in the southeastern part of Wyoming, extending from Colorado northward over a third of the distance across the state. It embraces nearly all the catchment area of the Laramie river, and on the east, beyond the Laramie range, it includes also the sources of the streams flowing easterly or northeasterly into the North Platte river. Within this county are the Laramie plains, which are in general character similar to the Great Plains to the east, but separated from these by the long, narrow Laramie range, a prolongation of the front range of the Rocky mountains. These plains lie at an altitude of about 7,000 feet, and the temperature, while favorable to the growth of forage crops and small grains, is too cold for many fruits and vegetables cultivated further to the east. Nothing grows without irrigation, but with it excellent crops of grass, alfalfa, the hardier cereals, and various vegetables are raised.

The Laramie plains are well watered on the west by the numerous tributaries which flow from the Medicine Bow mountains or Snowy range, and which either sink into the plains or flowing nearly across them unite to form the Laramie river. For a brief period in the spring, during the prevalence of the freshets, there is an ample supply of water, but during the summer there is not enough for all the ditches. Near the foothills on the west side of the plains are many small lakes, some of which are suitable for water storage, and plans have been suggested for constructing suitable regulating works for this purpose, few reservoirs, however, being in actual use. Besides these lakes in Albany county there are many good storage sites on the head waters of the Laramie river in Colorado, south of the county line.

Stock raising is the principal industry, forage forming 98 per cent of the total area of crops irrigated in 1889. As a general rule vegetables and cereals were raised in quantities sufficient merely for local consumption. Besides the crops irrigated there was an acreage of equal amount reported as irrigated for grazing, the total of these two items amounting to a third of the entire area of the farms of the county. The character of the irrigation for grazing is such that one man can apply water to large tracts whenever this is abundant and the cost is therefore very small. On the eastern side of the Laramie range, along the narrow valleys on the head waters of the streams flowing into Laramie county, are large areas of agricultural land. The country is rough and broken, and, as on the Laramie plains, grazing is far more important than tilling the soil. There is a complaint among the smaller farmers that the great corporations engaged in cattle raising interfere with the growth of agriculture by fencing enormous areas within which are lands susceptible of irrigation and legally open to settlement.

CARBON COUNTY is in the southern part of Wyoming, west of Albany county. The North Platte flows from Colorado northerly through this county into Natrona county, where it turns toward the east. The principal agriculture is in the valley of the North Platte, in the southern part of the county, where the river is bordered on the east by the Snowy range and on the west by the Sierra Madre. The ranches are located along the small streams which issue from these mountains, the land under cultivation being near the streams and irrigated by short ditches taken out by the owners of each ranch.

The water in these small streams diminishes rapidly in July, and from then until the middle of August, when the crops are cut, there is often scarcity of water. There is a large volume flowing in the North Platte at all times, and if the river could be diverted in the southern part of the county by large canals running near the foothills on each side of the valley, enormous tracts of fertile land could be utilized. At present the land lying back from the creeks and a little above the level of the bottom lands is of little or no value. The general altitude of the agricultural land is 7,000 feet. It is undulating and broken, being traversed in places by ranges of hills. The principal industry of the county is grazing, although the climate is favorable to the production of many of the grains. The expense of transportation is so great that nearly all the products are raised for home consumption. The ditches are mostly small, one of 15 feet in width being considered large.

In the southwestern corner of the county is a portion of the head waters of the Snake river, which flows southwesterly into the state of Colorado, finally emptying into the Green river. There are several ranches along this river and its tributaries, the irrigated lands being in the bottoms. The mesa land adjoining these has not as yet been touched on account of the expense of bringing water upon it. Taking the county as a whole, the amount of land taken up is insignificant in comparison with that which remains to be utilized, and there appear to be excellent opportunities for the development of large irrigating systems from the North Platte river and by storage from many of its tributaries.

Converse county is in the center of the eastern side of the state, lying north of Albany and Laramie counties. The average elevation is approximately 5,000 feet, the greater portion of the county consisting of the debatable ground between the Great Plains region on the east and the Rocky mountain foothills region on the southwest. The Platte river flows across the southwestern corner of the county, receiving many small tributaries from the Laramie range to the south. The county line on the north running east and west lies approximately in the center of the valley of the south fork of the Cheyenne river, the divide between the Cheyenne and Platte being through the center of the county. In many places this is apparently so low that the farmers believe that a canal can be taken from the Platte river in Natrona county and brought out upon or across this divide. There are few ditches, and the area tilled is insignificant in comparison to that used for stock raising.

It is generally impossible to raise any crop without the application of water, although the rainfall is in many seasons almost sufficient to insure success. In the bottom lands, along some of the streams where the land is probably wet by seepage, potatoes and other vegetables have been produced, and in a few localities oats, wheat, and millet have been raised without irrigation, the crops being, however, only about one-half or one-third of those on the irrigated land. Large areas are now under irrigation for grazing, with the intention of bringing the land into condition for raising hay, two or more years of irrigation and grazing being usually considered necessary before a forage crop can be cut. Along the North Platte river several water wheels, carrying upon their rims buckets by which water is raised, are reported to be in use, but with results not always satisfactory. The lower lands along this river are of enormous extent, and with large and comprehensive canal systems, taking water from this river extensive tracts of fertile land can be reclaimed, there being apparently an abundant supply of water. The creeks coming into the North Platte from the south flow in general through narrow valleys, or have cut ravines, rendering it a matter of difficulty to take the waters out upon the higher and better lands. Many of these carry a considerable amount of water throughout the year, but in most instances there is an extent of land far greater than can be brought under irrigation by these streams without storage.

Crook county is in the northeastern corner of the state, adjoining Montana on the north and South Dakota on the east. In altitude it is, as a whole, as low as that of any county in the state, the northeastern corner being considerably under 4,000 feet in elevation, while the average for the county is under 5,000 feet. In the eastern part it contains the Bearlodge range, the northwestern prolongation of the Black Hills region. The summits of this range are 6,000 feet or more in altitude, Warrens peak rising to over 6,820 feet. The principal stream of this county is the Belle Fourche or north fork of the Cheyenne river. This stream rises in Weston county, flows northeasterly along the western foot of the Bearlodge range, and shortly before reaching the state line turns abruptly to the southeast, passing around the Black Hills. West of this stream, and separated by a comparatively low divide, are the head waters of the Little Missouri, and beyond this are those of the Little Powder river, the county continuing to the westward and embracing some of the tributaries of the Powder river.

The principal settlements of the county are in the Bearlodge mountains, where there are good ranges for stock, and where agriculture without irrigation is occasionally successful. The streams flowing in all directions from this range and finally uniting in the Belle Fourche furnish opportunities for irrigation on a small scale, and a number of ditches, owned by individuals, have been built, but as a general rule, although there is an ample supply of water at the time of the melting of the snow, yet later in the season, at the time when the waters are needed for maturing the crops, the streams become nearly or quite dry. The principal tributary of the Belle Fourche in this county is the Inyan Kara, which flows in a general northwesterly direction south of Sundance. The banks of this stream are high, and ditches are taken out with difficulty. There is an ample supply of water in the early spring, but the stream has been known to become nearly or quite dry in the fall. The valley of the Belle Fourche itself is narrow and is bounded by high bluffs, the river crossing from side to side, rendering the construction of a comprehensive canal system difficult, if not impossible. The Little Missouri often contains a fair amount of water, but in 1889 and 1890 it was dry in many places, the extraordinary drought of the last two years having its effect upon all these streams as well as upon the crops. The farmers in general state that although they can occasionally raise corn, wheat, oats, and vegetables without irrigation, yet at best the yield is small and they can not be sure of a crop two years in succession.

FREMONT COUNTY, in the western part of Wyoming, comprises a large area extending from the Montana line southward two-thirds across the state, including the Wind river and other head waters of the Bighorn, and extending south over the continental divide, including New Fork and various small tributaries of the Green river. On the southeast are the head waters of the Sweetwater, the county thus including portions of three large drainage basins. The Wind River range, which crosses the county diagonally, lying in a general northwesterly and southeasterly direction, and the southern extension of the Absaroka range on the north are of such a height as to give rise to innumerable streams, so that as a whole the county is well watered. The greater part of the population is in the vicinity of Lander and neighboring towns in the center of the county. Mining is an important industry, although perhaps not as important as stock raising. The Wind River Indian reservation north of Lander occupies a large part of the county, but south of it agriculture has developed along the Popo Agie river and its tributaries, where the water supply in general is remarkably good. In the east of the county, on the Badwater creek, irrigation is less successful, but on the Sweetwater to the south the water supply is reported to be plentiful for the land under irrigation.

There are no large canals in the county, but many small ditches, each taking water to the lands of one or two owners. Owing to lack of transportation facilities there is little or no market for agricultural produce except at the mines. Much of the agricultural land is rough, requiring considerable expenditure to prepare the surface for thorough irrigation. An occasional crop of barley or oats is reported to be successful without the application of water. In the southwestern corner of the county, south of the head waters of the Green river and east of New Fork, is a vast plain lying at an altitude of about 7,000 feet. The elevation of the plain above the channels of the streams is so great, however, that it is doubtful whether water can be brought out upon it. The water supply of that region is good, but compared to the vast area of land suitable for forage crops at least is wholly inadequate. Settlement has been confined to the foothills, where water can be had in abundance.

The north portion of Fremont county is probably the best watered part of the state, for it contains in its western half a part of the Absaroka range, the peaks of which rise to altitudes of from 9,000 to 11,000 feet. Settlement is progressing rapidly on the principal streams which flow from these mountains, and there appears to be no immediate possibility of the water supply being exhausted, at least on the Grey Bull and rivers to the north. On Owl creek, north of the Wind River Indian reservation, some difficulties are reported on account of diversions of water by settlers toward the head waters. In the valley of the Bighorn river is a large amount of good agricultural land and plenty of water, but the banks of the river are high and the fall is so gentle that the expense of taking out canals appears to be large, too great at least for the present settlers to attempt. The lack of a railroad retards development, and the agricultural resources are little known by those outside the county. There are high water ditches, which in times of flood water some of the lower lands in this valley.

JOHNSON COUNTY is in the northern part of Wyoming, separated from Montana only by the comparatively narrow strip of land embraced in Sheridan county. It extends from the summits of the Bighorn mountains eastward toward the Great Plain region, and covers a region most favorable for the development of irrigation, the high mountains on the west contributing a perennial supply of water for the open valleys toward the east. The tilled lands lie in the valleys along the base of the mountain range at altitudes of from 4,000 to 6,000 feet. The streams coming from the Bighorn mountains unite in creeks, which flow in a general northeasterly or northerly direction and finally, after crossing through the foothill and high plain region, empty into the Powder river, the waters of which, flowing northward into Montana, join those of the Yellowstone. The irrigation streams coming from the high mountains fluctuate to a certain extent during the day owing to changes of temperature, the amount of water following a hot summer day being noticeably greater in amount. Within the past few years agriculture has developed to a wonderful extent along the base of the Bighorn range, and there has been brought under cultivation an area of land so extensive that it can not be completely watered by the streams, although their flow is comparatively large and persistent, and the farmers report many acres of crops ruined in 1889 and in 1890 on account of this deficiency of water. In this county the small amount of snow during the winters preceding 1889 and 1890 has had its effect upon the streams in the reduction in their volume.

No crops can be raised with certainty without irrigation, although a few acres of potatoes and vegetables have been reported as successful without the application of water. Some native hay also is thus raised, especially in seasons of unusual rainfall, and many farmers consider this hay better in quality than that raised by irrigation, but the quantity per acre is far less. One cutting of alfalfa is occasionally obtained without the use of water. The ditch system of this county, like that of many other parts of the west, has grown up in a haphazard fashion without definite plan. In most instances the ditches have been built to convey water to a single ranch, and are to a large extent owned by individuals or cattle companies. Consequently the majority of them are small and imperfectly constructed, and the losses that have occasionally resulted have arisen from defects in the ditch rather than from lack of water in the stream, although the water is not in general sufficient for all demands.

In seasons like those of 1889 and 1890 the scarcity in many cases brought about a temporary agreement between various persons claiming water from the same stream, according to which the whole amount of water available was distributed alternately to the different ranches, resulting in economy, and consequently covering a larger area than before. The over appropriation, however, on Clear creek and on several branches of Crazy Woman creek, has led to vexatious disputes. In many cases where the water can not be had during the crop season it has been found of advantage to apply water later in the season, and late irrigation in general has proved a great benefit. Water storage has been undertaken to a very small extent. One man in particular reports the successful use of a small reservoir in which spring water is held.

LARAMIE COUNTY is in the southeastern corner of Wyoming, east of Albany county, thus including the lands east of the foot of the Laramie range and south of the divide between the North Platte and Cheyenne rivers. The western side of the county is well watered by the many small streams which, rising in the Laramie range in Albany county, flow eastward to join the North Platte river. This river enters the northwestern corner of the county and flows toward the southeast into Nebraska. Its waters are not diverted, except in a small way, upon the bottom lands, as for a great portion of its course through the county the narrow river valley is bounded by bluffs, rendering the expense of canal construction too great for private means.

The eastern side of the county has an altitude of about 5,000 feet, and is in no way different from the Great Plain region of western Nebraska and Kansas. Stock raising is the principal industry, and there are many ranches embracing thousands or even tens of thousands of acres. Dry farming has been attempted, but it is only occasionally that a crop can be raised. Many settlers came into the county during or shortly after 1884, the year of unusual rainfall, expecting that, according to the prevalent ideas, the rainfall would continue to increase. In this they have been bitterly disappointed, and year after year of repeated failures has led them to believe that without irrigation agriculture can not succeed.

On the western side of the county, where the elevation is 6,000 feet and upward, no attempts at dry farming have been made, but the soil wherever tilled is irrigated, except in a few instances among the hills at the southern end, where potatoes, rye, wheat, and oats sometimes do well without irrigation. The waters of the many small creeks have all been appropriated, and as a usual thing the rights to the waters largely exceed the amount available, except in times of unusual floods. In the summer there is scarcity, and losses of crops are reported. There are many storage sites on the heads of these streams, especially in Albany county, and in a few instances small reservoirs have been made and are in successful operation. Nearly all the small tracts along these streams are owned by individuals, but there still remain great areas higher and more remote, to which water can be brought only after a great expenditure for canals and storage works.

The Laramie river, flowing through the range of the same name, joins the North Platte in the northern part of the county, Fort Laramie being placed at the junction of these streams. On the bottom lands along the North Platte river are ditches, which take water whenever the river is high, and thus serve to thoroughly saturate these bottoms during the flood season. At other times of the year, however, these ditches are too high to obtain any water from the streams. These bottom lands are usually sandy, and require more water than do the bluff lands, which are reported to be superior for agricultural purposes, if only the water could be brought upon them. The largest irrigation project in this part of the state is that of the Wyoming Development Company, whose canal takes water from Laramie river, covering land between Sybille and Chugwater creeks. The canal soon after leaving Laramie river passes through a tunnel and discharges its water into a branch of Blue Grass creek, which in turn empties into Sybille creek. Here the water is again diverted into the second portion of the canal, about 35 miles in length and 25 feet wide on bottom. About 12 miles farther down the creek is another branch 20 miles in length and 20 feet wide on bottom. Both of these run in a general northeasterly direction, furnishing water to a number of laterals.

The streams which flow into the North Platte from the northern end of the county drain a low catchment area, and therefore have very little water in comparison to the extent of country drained. Advantage is taken of the spring floods to soak the lands, and all of the water that can be taken from the streams is thus used, in the hope that by the fortunate occurrence of rains the crops may reach maturity. The soil along these creeks is usually too sandy, and the results are not always successful. South of the North Platte river, on the plains forming the divide between Horse creek, a tributary of the North Platte, and Lodge Pole creek, which flows into the South Platte, as well as along these creeks, are many ranches, most of the farming being done, however, on the high lands. Occasionally crops of potatoes, millet, oats, corn fodder, sorghum, and vegetables are raised, and in a few instances windmills are used to pump water for apple trees and various kinds of fruit. Corn is reported as usually unsuccessful, owing to the early frosts. In the lower bottoms, where some water is received by seepage, potatoes and vegetables are more certain of success.

NATRONA COUNTY is east of the center of the state and north of Carbon county, of which it formerly was a part. The North Platte flows across the southeastern corner of the county, and the Sweetwater extends along the southern border to the point where it flows into the North Platte. Neither of these rivers, however, although carrying a large amount of water, is used to any extent for irrigation on account of the difficulty of building canals from them. The agricultural land at present cultivated is along the creeks flowing into these streams from the Laramie or the Rattlesnake range, the water being diverted by various private ditches. Hay is the principal crop, the altitude of the county being about 6,000 feet. Although the tilled land is confined to the valleys along the smaller streams, this is not due to lack of arable land, for on the higher lands back from the creeks are immense tracts as good as that now tilled. There is need of careful examination to determine where, if possible, canals can be taken from the large streams to cover this valuable land. At present the waters of the smaller streams are in several instances used to their full amount and more water is needed, the irrigators stating that water storage would be desirable.

Sheridan county is in the center of the northern side of Wyoming, and extends from the summits of the Bighorn mountains easterly to the valley of the Powder river, embracing in its eastern end a portion of the deeply eroded plains region sometimes designated as "bad lands". The Bighorn range rises to elevations of from 8,000 to 12,000 feet, and from it issue innumerable streams, fed by the snow on these lofty slopes. The streams which rise among the high mountains furnish a perennial supply of water, but those whose origin is among the foothills farther to the east are more unstable in their character. The comparatively low altitude of the agricultural lands of this county more than compensates for their high latitude. Around Sheridan the elevation is reported to be only 3,500 feet, the valley of the Tongue river being perhaps the lowest land in the state. The towns and settlements are along or among the foothills, and depend for their existence upon the stock raising and agriculture carried on along the streams. Great enterprise and energy have been shown in developing the agricultural resources of this county; large areas of land have been taken up and a portion of these brought under cultivation.

It is evident that there is not enough water to irrigate all of the land filed upon, not taking into consideration the vast areas still open for settlement, and the irrigators demand some method of water storage. There are many favorable reservoir sites in the Bighorn mountains, and several have been mentioned in the vicinity of Cloud peak. One or two small reservoirs have already been built and operated successfully. Irrigation construction has been done in a small way, each individual usually taking out his own ditch. The banks of the streams, especially of those eastward from the foothill region, are steep and high, so that canal construction is expensive. In the progress of irrigation the water is used first on the low bottoms, and in but a few instances is it carried back upon the bench land. Owing to the unregulated flow of the streams the cereals can not be raised as successfully as the forage crops, as the water becomes scarce at the time of the filling of the grain. Without irrigation crops are raised one year in five, but even then the yield is not as large as on irrigated land. The tributaries of the Tongue river, such as Goose creek, Wolf creek, Hughes creek, and other streams heading in the mountains, are well adapted for irrigation purposes, but those of the Powder river in this county, as for instance Clear creek, being farther from the mountains, are less favorable on account of the slight fall, the high banks, and the irregularity of flow. Almost every ranchman along Clear creek has his own ditch. The Powder river offers many difficulties to canal construction, and during the critical periods of summer may be nearly dry.

Sweetwater county is in the southern part of the state, west of Carbon county, including a great part of the plain region which here is in the course of the continental divide. This region is not a plain in the strict sense of the word, the surface being in many places undulating and rough, but, on the other hand, it is not marked by decided ranges of hills. The elevation is approximately 7,000 feet, and the country is extremely arid. The little irrigation in the county is principally along the tributaries of Green river south of the town of Green River, there being a small amount on the Big Sandy at the northern end of the county. In the northern part of this county and extending into Fremont county is an extensive plain, bounded by Green river on the west. There are projects for taking water out upon a portion of this level country, but the difficulties to be overcome are great on account of the low elevation of the water relative to the bluffs which border the plain. South of Sandy creek and between it and Bitter creek is another tract of great extent, and it is probable that attempts will be made to bring water upon a part of it at least. South of the railroad the country is more rolling or broken, but farming is carried on along the small streams, the products being mainly for home consumption. Near the town of Green River the attempt has been made to irrigate by means of water raised by a steam pump, but satisfactory results have not as yet been reported.

Uinta county occupies the western end of the state, being a long, narrow strip extending from the Yellowstone national park to the Utah line. It thus includes on its western edge a portion of the Bear River valley, and on the east a large part of the head waters of Green river. In the northern end of the county are several lakes at the head of Snake river, which flows southwesterly into Idaho, and descending rapidly crosses the great lava fields of the southern part of that state. These lava plains, lying at an elevation of from 4,500 to 4,700 feet, are of great fertility, and when the waters of the Snake are taken out upon them they will be of incalculable value. The lakes and reservoir sites in the northern part of Uinta county have thus a great prospective value to the state of Idaho.

The greater part of the arable land is at an altitude of about 7,000 feet. The country in the southern part at least is rolling, and the hills do not rise sufficiently high or steep to add to the water resources of the county. The Bear river, rising to the south among the lofty summits of the Uinta mountains, flows northerly through the southwestern corner of the county, then turns to the west into Utah, again turns to the east and flows along the western border of the county, finally passing out into Idaho, where its waters in time of flood enter Bear lake and at other times, continuing through the corner of Idaho, turn southerly into Utah again, finally being lost in the Great Salt lake. Along the valleys of the Bear river in Wyoming are great hay ranches, comprising thousands of acres, and the water is used to a large extent. There are many excellent reservoir sites on the head waters in Utah, and the utilization of these is a matter of importance to communities in Wyoming, Idaho, and Utah.

On the eastern side of the county are many small streams which flow easterly from the high plateau or hilly country into the Green river, on the farther side of which is the great plain of southern Fremont county. The waters of these streams are used on the hay ranches in the narrow valleys, but the altitude is too great for the success of most agricultural products. It is stated that frosts occur nearly every month; for example, that in the past 10 years there have been only 4 months without frost. Some oats are raised and small crops of potatoes, and alfalfa has been tried, but without success. As a general thing there is plenty of water for all claimants, conflicts regarding rights being reported only in a few cases.

In the high, rolling country the principal dependence of the irrigators must be upon the winter snow and the local storms. There are many good storage sites. The situation of this county with regard to storage systems is somewhat peculiar, from the fact that, as before stated, it contains the best location for storage works for Idaho, and, on the other hand, the reservoir sites on the Bear river are in Utah. Besides stock raising, the important industry of the county is coal mining, and the southern end of the county is comparatively well provided with transportation facilities, two railroads crossing and occupying the most important valleys.

WESTON COUNTY is in the eastern part of Wyoming, lying south of Crook county, from which it was formed. It is west of the Black Hills, and contains a portion of the head waters of the streams which, flowing northerly or southerly, pass around the Black Hills and unite to form the Big Cheyenne river. The altitude of the county is about 5,000 feet, the greater part of the area being of the Great Plains type. Agriculture without irrigation is rarely successful, although crops of small grains, potatoes, and vegetables have been raised in years of unusual rainfall. Irrigation is comparatively new and is imperfectly carried on, the ditches being small and depending upon the unregulated flow of the streams. Water storage has not been attempted, although the creeks fluctuate greatly and are dry during the latter part of the crop season. The tilled areas are principally at the eastern end of the county, along Beaver creek and its tributaries, being thus in the vicinity of the mining regions in the Black Hills.

THE SUBHUMID STATES.

In the subhumid states, namely, North Dakota, South Dakota, Nebraska, Kansas, and Texas, 66,965 acres, or 104.63 square miles, were irrigated in the census year ending May 31, 1890. The aggregate number of farms upon which irrigation was practiced was 1,552, the average number of acres per farm being 43. The term "subhumid" as applied to extensive areas in the United States includes belts of country on each side of the arid region, these forming the debatable ground between it and the comparatively well watered regions east or west. The western subhumid region is much narrower than that on the east and the states crossed by it lie for the greater part within the arid region. On the other hand, the subhumid region on the east, crossing broad prairies, includes the greater part of the states above named. In this discussion of irrigation by states and territories it becomes a matter of convenience to classify these states under the one designation of subhumid, although their eastern ends are within humid regions, and in the case of Texas, at least, the western prolongation lies far within the arid region.

The following table gives for each of the states under discussion the number of irrigators and other items. This table has been obtained by compilation of the enumerators' returns for each irrigator in these states. Classifying these according to size, it has been found that of the 1,552 irrigated areas 7 were of 640 acres or upward, 12 of from 320 to 640 acres, and 40 of from 160 to 320 acres. These 59 areas contained an average of 341 acres each, or in all 20,146 acres, a little under one-third of the entire amount in the 5 states. The remaining 1,493 irrigated areas, under 160 acres in size, averaged 31 acres each and comprised 69.92 per cent of the total.

NUMBER OF IRRIGATORS, AREA IRRIGATED, AND AVERAGE SIZE OF IRRIGATED FARMS IN THE SUBHUMID STATES IN 1889.

STATES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.
Total	1,552	66,965	43
North Dakota	7	445	64
South Dakota	189	15,717	83
Nebraska	244	11,744	48
Kansas	519	20,818	40
Texas	623	18,241	29

COMPARISON OF COSTS AND VALUES.

The average first cost of bringing water to the land throughout these 5 states, as estimated from the statements of the farmers, was $4.07 per acre, while the average selling value placed by the irrigators upon their water rights wherever these were transferable was $14.81 per acre. The average annual expense of water rental or of maintaining the ditches was $1.21 per acre, and the average cost of preparing the ground for cultivation, excluding the cost of bringing water to the land, was $4.62 per acre, as given by the farmers.

In the following table the more important of the foregoing statements are compared with those for the adjoining states on the west, namely, Montana, Wyoming, Colorado, and New Mexico:

COMPARATIVE CONDITIONS OF IRRIGATION, SUBHUMID AND OTHER STATES, 1889.

ITEMS.	Montana.	Wyoming.	Colorado.	New Mexico.	Subhumid.
Area irrigated in census year, in acres	350,582	229,676	890,735	91,745	66,965
Number of irrigators	3,706	1,917	9,659	3,085	1,552
Average size of irrigated farms, in acres	95	120	92	30	43
Average size of irrigated farms of 160 acres and upward, in acres	307	494	307	312	341
Per cent of acreage of irrigated farms of 160 acres and upward to total acreage irrigated.	50.37	65.18	49.34	21.45	30.08
Average size of irrigated farms under 160 acres, in acres	56	50	55	24	31
Average first cost of water rights per acre	$4.63	$3.02	$7.15	$5.58	$4.07
Average annual cost of water per acre	$0.95	$0.44	$0.79	$1.54	$1.21
Average first cost of preparation for cultivation per acre	$8.29	$8.23	$8.72	$11.71	$4.62

GENERAL DESCRIPTION.

The country under discussion forms part of the Great Plains region lying west of the Mississippi and extending to the base of the Rocky mountains. The surface of this plain rises as a whole toward the mountains, the increase altitude on a line through Kansas and Colorado, for example, being from 1,500 feet up to 5,000 feet in a distance in of 400 miles, or under 9 feet per mile. The Rocky mountains in the northern half of their length in the United States have a decided trend to the northwest, and the plains sweep around far to the west, extending in northern Montana even beyond the meridian of Salt Lake city. Taking any north and south line nearly at right angles to the greatest slope and passing, for example, through western Kansas, it is found that the plains for the most part descend from the south toward the north, the highest points being on the Llano Estacado of Texas, where the general altitude is about 4,000 feet. On going northerly from this locality, and neglecting the river valleys, the surface through western Kansas is found to be at an altitude of about 3,000 feet, continuing, with slight undulations, to South Dakota, where the surface is about 2,000 feet, finally dropping off to or even below 1,500 feet on the north line of Dakota. This gradual northerly slope of the Great Plains counteracts to some extent the differences in climate due to the position farther to the north, so that the contrasts in temperature and in other climatic factors are not as great as might be expected.

The soil of this region, taken as a whole, is as rich as that of any part of the United States, and in almost every respect, save that of moisture, the country is an ideal one as regards agriculture, but unfortunately the lack of rain at critical times during the summer, together with the occasional hot winds so destructive to vegetation, renders doubtful the success of farming by ordinary methods. The amount of rainfall and the time of occurrence vary widely from year to year, decreasing as a whole for a few years and then increasing for longer or shorter periods, the duration of these oscillations being a matter of uncertainty. These nonperiodic oscillations of the annual rainfall are more noticeable in such a country, where in ordinary years there is hardly enough to mature the crops, for in the years when the amount of precipitation during the summer is a little above the average the crop yield may be phenomenally large. On the other hand, during years of scanty rainfall the crops usually fail, reducing the population to the verge of famine.

These changes in the amount of moisture and the consequent success or failure of crops have resulted in great hardship to most of the settlers, who, coming with small means and no experience in farming in such a climate, have lost their property and have been saved from starvation in many instances only through outside aid. Thousands of families have been compelled to leave their homes. Among the special schedules of the Census Office there are hundreds of statements reciting the desperate situation of the people, especially in the year 1890, with many touching appeals for aid. Although a large number of families have left this subhumid area, others are constantly coming in, and the population as a whole does not show the rapid decrease which might be expected from an examination of individual statements. The change in population is perhaps best shown by the statistics for western Kansas, in which state an annual census has been made. Taking, for example, the counties of Norton, Graham, Trego, Ness, Hodgeman, Ford, and Clark, and all those to the west of these, the total population, as shown by the state census was, in 1883, 20,942; in 1884, 23,957; in 1885, 33,758; in 1886, 85,193; in 1887, 138,283; in 1888, 138,717; in 1889, 121,071, and in 1890, according to the Eleventh Census of the United States, 102,394. According to these figures the greatest population was in 1888, this declining in 2 years by 36,323.

In many respects the settler in a subhumid country is less fortunate than one in the arid region, especially if his means are scanty. In order to secure the title to his land he must of necessity expend nearly or quite all of his money, and if his first crop is a failure his situation is desperate. Many a man in spite of this has been induced to endure great hardships in the hope that the succeeding year might be favorable and the crops approach the wonderful yield of which he has perhaps seen examples. More than this, there have been hopes held out of a permanent change in the climate, or that water can be procured in some novel way, or the rainfall increased by mechanical effects. On the other hand, the settler in the arid region knows that there can be no hope of success except by irrigation, and if he secures a water supply he is reasonably certain of success, and is not called upon to endure years of privation while experimenting in methods of agriculture or waiting for a fortunate season.

The fact that there is nearly enough rain to insure the success of crops in the subhumid region is not as great a benefit as is often inferred, for, as stated above, farmers are induced to take chances on the fortunate occurrence of rain at critical times, and in the long run they are disappointed. It is difficult to convince the people in many localities of the necessity of developing to the utmost capacity every possible source of water supply and of maintaining and pushing forward the work even during years of unusual precipitation. There is a tendency to neglect systematic effort in this direction, and schemes projected in one year are sometimes dropped in the next. There are many localities where, in spite of poverty, it would be possible by united and persistent application to save storm water or develop other sources of supply. Each year people are misled by some new theory which promises to increase the available moisture without involving the laborious construction of the class of works which have proved successful in the past. At one time they have been excited by anticipations of securing artesian water, again by hopes of employing the so-called "underflow" or the ultimate success of the rain makers.

In view of the many failures reported from western Kansas and Nebraska, it is surprising to note the large acreage in cereals in this part of the country. According to the agricultural returns for the census year there were raised in the 32 counties in the western end of Kansas 775,753 acres of cereals. Of this there were in barley 1,850 acres, in buckwheat 188 acres, in corn 523,030 acres, in oats 66,114 acres, in rye 58,324 acres, and in wheat 126,247. In the 25 counties in the western end of Nebraska there were in all 749,871 acres of cereals, and of this there were in barley 5,942 acres, in buckwheat 986 acres, in corn 484,391 acres, in oats 98,537 acres, in rye 19,041, and in wheat 140,974 acres. The population in these counties in Kansas was, as before stated, 102,394 and in the counties of Nebraska 103,188.

Although the area cultivated within counties in and adjoining the subhumid region appears in the aggregate so large, yet on the other hand the yield per acre is relatively small and uncertain. The number of failures can not be ascertained, but in 1889 and 1890 it was so large that the majority of the population were discouraged and impoverished. The possibility of irrigation has been received with great enthusiasm, and most of the easily available sources of water have been employed to a greater or less extent, as shown by the number of irrigators. Is is obvious that only a small proportion of the agricultural land can ever be irrigated, but these relatively small areas upon which valuable crops can be raised with certainty are of the greatest importance in promoting the prosperity of the communities in which they occur. If a farmer can be sure of obtaining from a small area an amount of produce sufficient to furnish food for his family he will be less dependent on the success of his grain crops, or can devote the greater part of his land to cattle raising. The principal obstacles to the introduction of irrigation, besides lack of water, have been the prejudice and ignorance of the people regarding the subject. It has been feared that if it were known that irrigation was necessary or even beneficial the reputation of the country would be injured. The sensitiveness on that point has tended to disappear, owing to the severe effects of the droughts of recent years, and there is a more general demand for the introduction of systems of water supply. For lack of knowledge of the best means of obtaining water and of applying it to the crops progress has been slow.

WATER SUPPLY.

The largest amount of water for irrigation is obtained from rivers which, heading in the Rocky mountains, flow in a general easterly course across the plains, emptying into the Missouri river or farther south into the Mississippi. These have an enormous drainage area and at certain seasons of the year carry a correspondingly large quantity of water. During the hot weather, when water is most needed, their channels, especially within the subhumid region, become nearly or quite dry. This is due both to losses by evaporation and to diversion of water by irrigating canals and ditches near the base of the mountains. Along each of these rivers, notably the Platte and the Arkansas, large canals have been built, receiving occasionally an abundant supply of water. Attempts have been made to increase and render perennial the amount of water in these canals by continuing them up the river and in a general way parallel to it at a grade less than that of the bed of the stream until they have penetrated water-bearing sands or gravel. The amount of water obtained in this way has been relatively small, but being available at a critical time it is valuable.

A source of water supply secondary only to that obtained from the large rivers is found in the springs or streams fed by them. These springs occur in great abundance in many parts of the eastern arid and the subhumid regions, water coming from coarse material, beds of sand and gravel, usually found below the surface marls. A small part of the rainfall finds its way down to these pervious beds, where it is stored, ultimately escaping wherever an opportunity occurs. The streams formed by the union of water from various springs are usually largest near their sources, dwindling in size rapidly from these points unless re-enforced by storm water. Their channels continue in a general easterly direction toward more humid regions, where the amount of water gradually increases, to be finally discharged into one of the larger rivers of the country. Many small ditches have been built, taking water at points a short distance below the springs and carrying it out to one or two farms.

The third source of water supply is from wells drilled or dug through the surface clays or marls down to the water-bearing sands and gravels, usually found at from 50 to 300 feet below the surface. A few of these flow, especially those upon the lower lands, but the great majority must be pumped, wind power being commonly employed. These wells seem almost inexhaustible by the machinery ordinarily used, and furnish water not only for domestic purposes and watering cattle but in many instances for gardens and trees. Their more extensive utilization for irrigation rests on the relative cost of raising the water and the value of the products. A small amount of irrigation has been carried on by means of storm waters held in suitable reservoirs. There are not many places where the topography of the surface is favorable for the construction of these, but all such localities will probably be utilized in the future.

The examination of sources of water supply points to the conclusion that outside of the canals in a few of the large river valleys the development of irrigation depends upon the utilization in each locality of all of the available water, either in large or small quantities and from whatever source it may come, whether from springs, wells, or storms, and that it is impossible to lay down any general scheme applicable to the country as a whole. Each community must ascertain for itself how and where water can be obtained if it is to be had, and having done so, the question as to whether the water can be profitably employed is to be answered only by the results of practical trial.

The average distribution of rainfall by months is comparatively uniform in the four northern states under discussion. Taking all of the rainfall data up to 1889, as furnished by the Chief Signal Officer, it appears that the average annual rainfall at all stations for the time during which observations were made was for the Dakotas 19.30 inches, for Nebraska 27.83 inches, and for Kansas 29.88 inches. These figures apply to the states as a whole, the average precipitation on the eastern side being greater and that on the western less than the figures given. The percentage of rainfall by months, on the contrary, is comparatively uniform across each of these states, to a certain extent, regardless of the total amount of precipitation. The following table gives in round numbers the average rainfall by months for the two Dakotas, Nebraska, and Kansas:

AVERAGE PER CENT OF MONTHLY RAINFALL FOR SUBHUMID REGION.

MONTHS.	Dakotas.	Nebraska.	Kansas.
January	3	3	4
February	4	3	3
March	5	5	5
April	12	11	10
May	15	14	15
June	15	16	14
July	16	16	15
August	12	11	12
September	7	8	8
October	5	7	7
November	3	3	4
December	3	3	3

From the above figures it is evident that April, May, June, July, and August are the rainy months, from 66 to 70 per cent of the precipitation occurring during this part of the year. This is peculiarly favorable in many ways to agriculture, rendering it possible to cultivate crops in localities where, judging from the mean annual rainfall alone, their success would appear doubtful. In Texas, as pointed out by General A. W. Greely, there is not the same uniformity throughout the state in the distribution of rainfall by months, there being more than one distinct type. Of the types mentioned by him two of most interest in this discussion are, first, that represented by the precipitation at Forts Sill, Griffin, and Elliott, in or near the "Panhandle" of Texas, and, second, that by the rainfall at Forts Bliss, Davis, and Stockton, in the extreme western prolongation of the state. Taking the average in each of these groups, it appears that the first agrees fairly well with the figures above given; but in the case of the second, the greatest rainfall occurs later in the season, coming in August and September, as shown by the following table:

AVERAGE PER CENT OF MONTHLY RAINFALL IN TEXAS.

MONTHS.	"Panhandle", Texas.	Western Texas.
January	3	2
February	4	3
March	3	4
April	9	3
May	15	7
June	13	9
July	11	14
August	10	20
September	10	20
October	11	9
November	5	5
December	6	4

NORTH DAKOTA.

In North Dakota irrigation was practiced in 1889 on farms in two counties, namely, Buford and Flannery, these being in the extreme northwestern corner of the state, north of the Missouri river. Water from artesian and pumped wells was used to a greater or less extent on gardens and fruit trees in the eastern end of the state, but in this connection these comparatively isolated cases have not been considered. In Buford county the irrigated land is in the vicinity of Williston, the irrigating ditches leading from Muddy creek and its tributaries, and also from Stony creek, both of these flowing into the Missouri. In Flannery county the land is watered from Beaver, Jones, and other short creeks flowing southerly from the high prairies. The ditches have been built by cattle owners mainly for the purpose of raising forage crops and produce for home consumption.

VIEW OF BELMONT CANAL NEAR HEAD, CHEYENNE COUNTY, NEBRASKA.

NUMBER OF IRRIGATORS, AREA IRRIGATED, AND AVERAGE SIZE OF IRRIGATED FARMS IN NORTH DAKOTA IN 1889.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.
Total	7	445	64
Buford	3	180	60
Flannery	4	265	66

GENERAL DESCRIPTION.

In various counties throughout the western part of North Dakota farmers state that although the soil is rich yet no dependence can be placed upon the crops. There is rarely rain enough through the summer to afford sufficient moisture, and in 1890 many of the settlers became completely discouraged and abandoned their homesteads. In Burleigh county, near the center of the state, it is reported that from 1880 to 1890 there were only three good crop years, namely, 1882, 1884, and 1885, the rainfall at other times being deficient, except perhaps in 1888, when the main losses were by frost. In any one county or group of counties it rarely happens that all farmers suffer alike. Usually there are local rains covering small areas, and thus one field or part of a farm may receive a fair amount of moisture while another part is dry.

It is impossible to draw any sharp line between the counties needing irrigation and those which do not, but it is sufficient to say that on the eastern edge of the state there is usually an abundant rainfall, while on the western side "dry" farming rarely succeeds. The water supply is not especially favorable for the growth of irrigation. In the eastern part of the state, in the James River valley and in that of the Red River of the North, are many artesian wells, but these can hardly be counted upon as a large factor in irrigation, being of far greater importance for domestic and municipal supply. Besides, irrigation is not really necessary, although of great benefit in increasing the yield per acre. The Missouri river flows through the state, entering near the northern end of the western side, and trending in a general southeasterly and southerly direction. In this part of its course the river has a fall of only about 1 foot to the mile, and diversion of its waters into short canals is almost if not quite impossible.

Flowing into the Missouri river from the north are a number of creeks, receiving water from springs or from the drainage of the prairie-like divide between the Missouri and Mouse rivers. Most of these streams are comparatively short, and some of them become almost, if not quite, dry during the summer. By means of a proper system of storage several thousand acres could be irrigated in the valley along the Missouri. On the south or west side of the river the opportunities for diverting water are even worse than on the east. Most of the perennial streams have cut deep gorges, in which there is no bottom land, and many of them fluctuate so greatly in quantity of water discharged that irrigation is almost impossible.

DIVERSION OF MISSOURI RIVER.

The practicability of diverting water from the Missouri river by means of a large canal built on a gentle grade has been frequently discussed, and hopes have been entertained that water could be brought over into the valleys of the James and Mouse rivers. It has been ascertained by the United States Geological Survey that the low water level of the water in the Missouri at the mouth of Milk river, Montana, is approximately 2,020 feet; at Fort Buford, at its junction with the Yellowstone, 1,855 feet; at Williston, Buford county, at the mouth of Muddy creek, 1,820 feet, and at Bismarck, Burleigh county, 1,620 feet. The elevations of the lowest points of the divide between the Missouri river and the drainage basins of the James and Mouse rivers have been ascertained to be as follows: north of Dog Den Butte in Church county the lowest points are over 2,100 feet, while south of it the lowest gaps are respectively 2,048 feet, 2,022 feet, 1,950 feet, and 1,923 feet, the last being at the head of Painted Woods creek. Where the Northern Pacific railroad crosses the divide the elevation is 1,870 feet. A ditch starting at the mouth of Milk river, Montana, and constructed on a uniform grade of 6 inches to the mile, would have to be about 450 miles long in order to reach the divide in Sheridan county south of Dog Den Butte. It would then have an elvation of a little under 1,800 feet, or 70 feet lower than the lowest gap mentioned. The line for a ditch on this grade would be at an average distance of about 5 miles from the Missouri for a length of 400 miles, leaving the river at about the northern side of McLean county and passing to the north of Turtle lake. The land below this line is rich and suitable for agriculture, but it is apparent from the above figures that such a project can hardly be considered as feasible.

The country examined in the course of this survey along the northern and eastern sides of the Missouri river is a rolling plateau deeply cut in a few places by coulees and bounded by bluffs along the Missouri river of from

200 to 400 feet in height. The divide between the Missouri and the rivers mentioned above is marked by low, irregular hills, at the base of which are many small lakes or lake beds, some of these being as much as 4 miles in diameter. Most of these lakes have no outlet and as a consequence they are strongly alkaline. From others a small amount of water escapes, but this soon disappears in the dry channel during the summer at least. It is obvious that water can not be held by storage in any of these lakes except by enormously increasing the drainage area and concentrating, if possible, the flowing water at a single point. The lakes fluctuate greatly, water accumulating during some years and then diminishing during several successive summers. The same is true of streams which drain large areas of this prairie country. The Mouse river and streams tributary to James river frequently cease to flow in summer, the water standing in pools in the beds.

The prairies northeasterly from the Missouri have a rich soil, which in years of abundant rainfall produces heavy crops of wheat. Settlement has progressed rapidly near the railroads, but away from these few inhabitants are to be found. There is good grazing over the entire area, and along the streams are a few trees. Most of them, however, have been cut off by the settlers. Attempts have been made to secure artesian water in a few localities. At Bismarck a hole was drilled to the depth of 1,200 feet, but without success. Ordinary dug or drilled wells usually find a supply at from 50 to 100 feet or more.

ARTESIAN WELLS.

Flowing wells have been found in the eastern end of the state in the valley of the James river, and that of the Red River of the North, which forms the boundary line between this state and Minnesota. By far the greater number of wells are in this latter area, there being but a few comparatively deep wells in the James River valley. The most northerly well in this area is that at Devils lake, in Ramsey county, which has reached a depth of 1,511 feet. This is 3.5 inches in diameter at bottom, and delivers water at the rate of 60 gallons per minute.

At Jamestown, in Stutsman county, about 85 miles south of the locality above mentioned, 2 other wells have been drilled, 1 to a depth of 1,523 feet. This is 8 inches in diameter at top and 3.5 inches at bottom. It delivers water at the rate of 167 gallons per minute. Another well has been drilled to the depth of 1,321 feet, but has been abandoned. At Ellendale, in Dickey county, 65 miles south of Jamestown, a well 4.75 inches in diameter was drilled in 1885 to the depth of 1,087 feet, at a cost of $4,000. This discharges at the rate of 1,700 gallons per minute, furnishing water for city purposes. The surplus is conducted for half a mile to a farm, where it is used for irrigation. These wells just mentioned all obtain water from what is known as the Dakota sandstone.

In the valley of the Red River of the North are a large number of flowing wells, both in Minnesota and in North Dakota. These range in depth from 100 to 200 feet as a general rule, though many are shallower or deeper. Taking the counties in order from north to south, these wells are reported in Pembina, Walsh, Grand Forks, Traill, Cass, Richland, and Sargent counties, North Dakota, and in Kittson, Marshall, Polk, Norman, Clay, Becker, Wilkin, and Traverse counties, Minnesota. All, or nearly all, of the wells in these counties obtain water from beds of sand and gravel buried beneath thick, impervious strata of clay, all of these being the result of glacial action followed by the effects of sedimentation from rivers and lakes.

The water from these wells is used almost entirely for household purposes and for watering cattle. The amount from any one well is usually small, and would be almost insignificant for use in irrigation if it were necessary to attempt this method of agriculture. As it is, there is an ample rainfall, and large crops are raised almost every year. The water is usually clear, cool, and agreeable to the taste, although it often contains a notable amount of saline matter. Even when too salty for household use cattle will drink it eagerly. Many of the farmers in North Dakota state that the water from their wells injures or even destroys vegetation, and that it will kill grass and willows in a short time. This effect is possibly due in many instances to the low temperature of the water, and in others to the saline contents.

Within the counties mentioned almost every farmer has his own flowing well, and, if the water is good, he finds it a great convenience. The cost of these wells was formerly $1 per foot for the first 100 feet and $1.50 for the second 100 feet. At a later time the ordinary contract price was 80 cents for the first 100 feet and corresponding rates for greater depths. Nearly all the wells are 2 inches in diameter, although there are a few 4 inches or larger. These are mainly deeper wells, which often have larger flow. For all practical purposes the shallow wells with small flow are as useful as the larger, since even the smallest supplies sufficient water for house and cattle. As a general rule, it may be said that the water from these larger, deeper wells is more liable to be salty and of less value for all purposes.

SOUTH DAKOTA.

Irrigation in South Dakota is practiced mainly in what are known as the Black Hill counties, on the western side of the state, namely, Butte, Lawrence, Meade, Pennington, Custer, and Fall River. In addition to areas in these counties a small amount of land is watered by means of artesian wells in the eastern part of the state. The streams in the counties mentioned rise in the Black Hills, and, flowing outwardly in nearly every direction, finally unite, those on the north forming the north fork and the others the south fork of the Cheyenne river, these streams nearly encircling this mountain area.

NUMBER OF IRRIGATORS, AREA IRRIGATED, AND AVERAGE SIZE OF IRRIGATED FARMS IN SOUTH DAKOTA IN 1889.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.
Total	189	15,717	83
Butte	43	4,282	100
Custer	22	1,754	80
Fall River	5	419	84
Lawrence	65	4,496	69
Meade	9	690	77
Pennington	45	4,076	91

Among the mountains at the altitude at which timber is found there is an abundance of moisture for cereals and grass. These are raised to a considerable extent in the valleys or parks of this area. Lower, among the foothills, the rainfall is usually deficient, and farming without irrigation can hardly be said to be profitable. Whenever the rainfall is more ample than usual wheat, oats, corn, barley, and millet are raised. Many of the farmers in these lower valleys make a living by working part of their time at the mines, and in this way manage to maintain themselves through years of drought. Some of the settlers, failing to raise crops for several years in succession, have abandoned their homesteads.

In the counties easterly from the Black Hills the rivers for the most part flow in deep, narrow channels 100 or more feet below the general surface. During certain seasons of the year they discharge a considerable amount of water, but in summer the streams gradually diminish until they almost, if not quite, disappear. The small amount of water available during the irrigating season, together with the unfavorable topography of the country, renders irrigation by ordinary means impracticable. Beyond the Missouri there are possibly a number of tributaries which, with storage, could be utilized, but at present the hopes of the farmers are centered upon the development of artesian waters.

WATER SUPPLY.

The principal streams used for irrigation in the Black Hills region are Redwater, Hay, Spearfish, False Bottom, Bear, and other creeks rising in the northern end of the mountains and flowing partly through Lawrence and Butte counties. On the east are Rapid and Battle creeks in Pennington and Custer counties, and on the south Beaver, Fall, and Cascade creeks in the southern part of Custer county and in Fall River county. The ditches taking water from the creeks to the land are usually small, having been constructed by individual farmers or by a partnership, each person of which is entitled to a certain proportion of the water.

The water supply is ample for the area now irrigated, but if the greater part of the ditches projected or under construction are completed there will undoubtedly be a deficiency, especially during the hot weather. Most of the streams flow throughout the year, but they become very low during the summer, and a comparatively small diversion of water at that time will leave the channels dry. The greatest development of irrigation is in the vicinity of Rapid, where there are from 8 to 10 ditches, a few of them of relatively large size. In the vicinity of Minnesela and to the south of it are also a number of ditches, and near Buffalo in Custer county. At this latter place a well 6 inches in diameter has been drilled to the depth of 800 feet in the hope of obtaining an artesian flow. Outside of the lower valleys around the Black Hills region are broken plateau and prairie lands stretching far away, upon which grazing is the only industry. Farming has been tried at various places, but with little success, principally on account of the lack of water and of the occasional occurrence of hot winds. The soil on many of these table lands between the streams is good and a few fair crops have been raised.

The Belle Fourche, or north fork of the Cheyenne, which receives the drainage from the northern part of the Black Hills, except in spring, is a small stream, and its banks are so high and the slope is so small that it will be hardly possible to divert any water upon the adjacent land. This, as previously stated, is the prevailing condition of the streams after they leave the foothills. There are a number of places in which reservoirs could be made, but for the most part these localities belong to individuals whose opposing interests prevent concerted action toward their utilization.

The Westside Water Supply Company has constructed a ditch from Redwater creek, heading about 1.5 miles southerly from the town of Minnesela, in Butte county, and carrying water out on the west side of the creek. It is about 5 miles long, 6 feet wide, and cost $1,500. The ditch was first used in 1890. Heading on the same stream above this ditch is the canal owned by the Redwater Land and Canal Company, taking water out toward the north and east. The total length is estimated to be 35 miles, average width 12 feet, and the cost was about $75,000. The canal was made by enlarging and extending two ditches purchased by the company. Water has been supplied to irrigators at the rate of from $1 to $1.50 per acre each year.

The Little Giant ditch takes water from Rapid creek, in Pennington county, running out on the north side of the valley. It is 4 miles long, about 5 feet wide, and cost about $2,400. It is owned by farmers, who divide the water among themselves. The Lonetree ditch takes water below the Little Giant, the head being about 8 miles southeast of Rapid. This ditch is 5 miles long, about 6 feet wide, and the cost was probably $4,500. In this valley, which is from 1 to 2 miles wide, the ditches are short and take water to comparatively few farms. The creek has a decided fall, and in places crosses from side to side, cutting into the bluffs on one side of the valley and then swinging across to those opposite. The various ditches, of which there are probably 8 in use, already cover the greater part of the farming land from about 3 miles west of Rapid down to a point 12 miles east.

ARTESIAN WELLS.

The flowing wells in this state, as in North Dakota, are found mainly near the eastern end, extending in a broad belt southerly down the James River valley to the Missouri, the greater number being found in the southeastern corner of the state and mainly in the counties of Bonhomme, Yankton, and Clay. A few shallow wells are found near the northeastern corner of the state, in Grant county, these being in all probability similar to those in North Dakota and Minnesota, and marking the southern end of the artesian area of glacial origin.

This state contains wells which have a very large flow. The amount of water from one of these wells compared to that generally coming from artesian sources is enormous. It is, however, usually greatly exaggerated, and it is difficult in a matter of this kind, where local pride enters so largely, to arrive at the exact condition of things. So far as can be ascertained probably the largest well does not deliver continuously over 3,000 gallons per minute, or 6.68 second-feet, although it has often been asserted that 1 or 2 of them flow at the rate of 10,000 gallons per minute. These large wells, in spite of the quantity of water they deliver, show no signs of exhausting the supply, although from analogy it is to be presumed that as the country develops the number of wells will be increased until the discharge begins to show signs of diminution.

Most if not all of the wells obtain water from the Dakota sandstone, which underlies the greater part of this state, as well as of North Dakota. Omitting the minor inequalities, as a whole, the distance from the surface to the Dakota sandstone becomes less in going from north to south or from west to east, so that the shallowest wells are those on the James river and Missouri bottoms in southeastern South Dakota. East of this region of shallow wells, and notably in Minnehaha county, the Dakota sandstone abuts against crystalline rocks, which come to the surface, and in which no flowing water is found, although a well has been sunk to a depth of 600 feet.

It should be noted that nearly all the more important wells, or at least those first drilled, are in or near towns, and that in many counties where wells exist none have been reported as being upon farms. This is due to the fact that the trial borings have been made mainly by municipal corporations or associations of citizens for the purpose of obtaining a domestic supply of water, and it is only in localities where the wells are comparatively shallow and inexpensive that they have been put down to any extent by farmers. It is obvious that the ordinary farmer can not incur the expense of deep drilling unless he has more than usual assurance of success.

Taking the counties in geographical order from north to south, the most northerly wells are in Brown county, which adjoins Dickey county, North Dakota. At Frederick a well over 1,100 feet in depth discharged, when completed, at the rate of 120 gallons a minute, while other wells at Columbia, Aberdeen, and Groton, averaging about 950 feet each, are reported to have discharged from 800 to 1,000 gallons a minute. In Marshall county, on the east, a well at Britton 1,000 feet deep flowed 850 gallons a minute. In Day county, at Andover, south of Britton and east of Aberdeen, a well 1,000 feet deep flowed 250 gallons a minute. In Edmunds county, at Ipswich, 30 miles west of Aberdeen, a well 1,270 feet in depth, is reported as discharging considerable quantities of soft, though slightly brackish, water.

Taking next the counties to the south, the largest number of wells is in Spink county, the depth being about 950 feet. These are found at Mellette, Ashton, Doland, Redfield, and other localities. Wells have also been drilled in Faulk county, to the west, and in Hughes, Hyde, and Hand counties, to the southwest, the well at Miller, in the last named county, being nearly 1,150 feet in depth, and discharging as high as 1,000 gallons per minute, and at Harold, in Hughes county, 1,450 feet deep, and discharging 150 gallons per minute.

In Beadle county, south of Spink, the most notable group of wells is at Huron, where the depth is about 900 feet. The discharge from some of the wells of this county is enormous, and the pressure is sufficient to furnish power for machinery, such as printing presses and flouring mills. The largest well probably flows at the rate of nearly 3,000 gallons a minute, or about 6.6 second-feet, and is reported to have thrown a 2-inch stream to the height of 90 feet. One well at least has been put down for irrigation on a farm near Huron. This well is 850 feet in depth, no water, however, coming in below 802 feet. It cost $1,800, is 4 inches in diameter, and discharges at the rate of 600 gallons per minute. In 1890 about 40 acres were irrigated and in the succeeding year approximately 100 acres. The pressure of the water at the surface of the ground is reported to be 120 pounds per square inch.

Southerly from this, in Sanborn county, are many comparatively shallow wells, which supply a small amount of water for ordinary uses. Little if any of this water is used for irrigation, since the amount from any one well is usually too small to be profitably employed. It is stated that the ground around some of these wells where the water is allowed to stand and evaporate becomes coated with alkali, and that plants have been killed by it. At Woonsocket are deep wells notable for their large amount of water and high pressure. One of them is reported to have thrown a 4-inch stream 70 feet in height for a period of over five minutes, and to have a discharge of about 2,700 gallons per minute, or 6.2 second-feet. Such wells as these will be of great value for use in irrigating during years of deficient rainfall.

In Miner county are many shallow wells similar to those of Sanborn county. Some of these wells of 100 feet or more in depth do not flow, although the water rises nearly to the top. In Jerauld county, west of Sanborn, a well has been drilled to the depth of 799 feet, the water obtained, however, being alkaline and carrying a small amount of oil. Other attempts, with possibly better success, have been made. In the next tier of counties to the south many wells have been drilled, those near the western end being the deepest. For example, in Brule county, wells at Chamberlain and Kimball have depths of 1,000 feet or more, and in Aurora, at Plankinton, and in the vicinity of White Lake, depths of about 900 feet, all of these yielding large quantities of water.

In Davison county, south of Sanborn, are comparatively few wells, and most of them are less than 200 feet in depth. Irrigation has been tried by means of water from these wells, and it is stated that the results have in the main been successful. Where failures are reported it is probable that water has not been applied skillfully. In Hanson, east of Davison county, the conditions are very similar, the wells, which are comparatively shallow, being put down primarily for watering cattle and for household uses. Very little of the water has been used for irrigation, and in many instances the surplus water from the wells is regarded as a nuisance, since it occasionally injures vegetation, especially where the ground is already naturally moist.

In McCook county comparatively few flowing wells are reported. There have been a number of failures, the drillers striking, it is stated, the hard crystalline rock, which bars further progress. The water from the successful wells sometimes carries small amounts of iron, sulphur, and other minerals, and a little petroleum. There have been a few crop failures, and the farmers look upon irrigation as occasionally necessary. In Turner and Hutchinson counties, south of McCook, the wells are quite shallow, being generally from 80 to 100 feet in depth. They discharge small quantities of water, none of which, so far as reported, is used for irrigation. In Douglas county, west of Hutchinson, a well has been bored at Armour to a depth of about 750 feet, furnishing water for town purposes at the rate of 1,400 gallons per minute.

In Bonhomme, Yankton, and Clay counties, lying along the north side of the Missouri river, the wells are mainly from 300 to 400 feet in depth and furnish from 100 to 200 gallons per minute. They are found mainly on the lower grounds near the river and in the James and Vermilion valleys. In Clay county they are so common that it may be said that there is one on nearly every farm. For stock and household use there is no question as to the value of the water and the great benefits derived from these wells, but on the subject of irrigation there is a wide range of opinion. A few farmers state that by proper use of water the yield has been remarkable, especially during the first year. Others state that during the second year the results have not been as good; that by too lavish use of the water alkali has developed upon the surface. Still, others state that the water from their wells, if applied to the surface, destroys all vegetation. How far the last mentioned opinion is the result of ignorance in applying the water or of prejudice against its use it is impossible at this time to judge.

The wells in this part of South Dakota, especially on the low grounds, are rapidly and cheaply made. The prices quoted are from $75 for a 2-inch well of a depth of 275 to 300 feet up to $300 for a 3-inch well of from 300 to 350 feet in depth. As a matter of course, the older wells, or those first put down, have in general cost more than would be the present prices for the same work. Upon the prairie, above the valleys, the wells cost more, from the fact that they must of necessity be deeper and are more liable to encounter gravel and stones. Thus the cost is from $250 to $300 for a 2-inch well and from $400 to $1,000 for one 3 or 4 inches in diameter.

The pressure of many of these wells, especially those on the lower ground, is sufficient to operate small machinery, and farmers use water wheels for driving churns and cornshellers and doing other work. In a few instances the wells operate water rams, forcing a small quantity of water to buildings high on the bluffs overlooking the river valleys. In Vermilion valley some of the wells do not flow, the water only rising within 30 feet of the surface. In others the flow has decreased owing to stoppage by sand, and many require frequent cleaning in order to keep the water running.

Attempts to secure flowing water have been made in the western half of the state, but comparatively few of these are successful. Exploration, however, is rapidly going forward, and it is only a question of a comparatively short time before the wells at various towns will by success or failure outline the limits of the artesian area. The only drilling in the extreme western part of the state as yet reported is one in Pennington county, 350 feet in depth, from which no water is obtained.

NEBRASKA.

In the following table are given in alphabetical order the counties within which irrigation was carried on during 1889. In the description, however, following the table, these counties, for convenience, have been grouped according to their geographic position. The figures of cereal production of the state show that the total area devoted to the cultivation of cereals in 1889 was 7,961,969 acres. Taking all the counties in the western part of the state lying beyond the one hundredth meridian, it has been found that cereals were raised upon 749,871 acres, over one-half of this area being in Indian corn. Comparing the irrigated acreage with the cereal crop alone in this part of the state, it appears that all of the land upon which crops were raised by irrigation was only 1.57 per cent of the area upon which small grains were produced. In this part of the state, where the climate is semi-arid, the average yield of the cereals per acre was considerably less than in the state as a whole; for example, Indian corn yielding 17.33 bushels against 39.40 bushels per acre for the whole state, and wheat 11.27 bushels against 13.23 bushels per acre.

NUMBER OF IRRIGATORS, AREA IRRIGATED, AND AVERAGE SIZE OF IRRIGATED FARMS IN NEBRASKA IN 1889.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of farms irrigated in acres.
Total	214	11,744	55
Banner	4	218	55
Cheyenne	36	3,154	88
Dawes	12	267	22
Deuel	4	125	31
Dundy	4	41	10
Keith	6	295	49
Kimball	11	441	40
Lincoln	37	3,049	82
Redwillow	3	72	24
Scotts Bluff	70	2,753	39
Sheridan	4	13	3
Sioux	23	1,316	57

NORTHWESTERN COUNTIES.

In Dawes and the adjoining counties of Sioux, Boxbutte, and Sheridan, in the extreme northwestern corner of Nebraska, are a few small irrigating ditches taking water out upon low land or meadows along the streams. The water is used mainly upon hay lands and for gardens or small patches of vegetables upon cattle ranches. The principal streams from which water is derived are Hat creek, which flows northerly into the south fork of Cheyenne river; White river, which also flows northerly into South Dakota, and the head waters of Niobrara river, flowing easterly near the state line. The water comes mainly from springs, and the streams do not fluctuate as widely or with the regularity of the snow fed rivers of the Rocky mountains. The supply as a whole is very small and wholly insufficient for the needs of any general system of irrigation. In order to extend the area cultivated in this manner it will be necessary to store all of the water that can possibly be held, utilizing each favorable depression.

The total area devoted to cereals in these four counties in 1889 was 146,163 acres. Of this there were in barley 3,492 acres, in buckwheat 385 acres, in Indian corn 58,365 acres, in oats 37,307 acres, in rye 2,449 acres, and in wheat 44,165 acres, the latter producing an average of 11.43 bushels per acre. There have been a number of years in which crops have failed entirely. In 1887 and 1888 the yield as a whole was good, but the light rainfall of 1889 and 1890 did not furnish sufficient moisture and the crops were almost a complete loss, so that hundreds of farmers were without seed for the following year. The soil throughout this area is rich and with moisture produces abundantly. The hot winds, however, are apt to occur during the summer, and there have been heavy losses from hail. Water for ordinary purposes is obtained from wells of from 50 to 150 feet in depth. One well in Sioux county is reported to be 298 feet deep, and the water is strongly impregnated with oil.

COUNTIES ALONG NORTH PLATTE RIVER.

The counties of Cheyenne, Deuel, Scotts Bluff, Banner, and Kimball form the southwestern corner of the western prolongation of Nebraska. The North Platte river flows diagonally through this portion of the state, and the South Platte crosses a corner of Deuel county, the two streams uniting some distance further to the east. On the south is Lodgepole creek, which flows easterly from Laramie county, Wyoming, through Kimball, Cheyenne, and Deuel counties, entering the South Platte. Throughout these five counties agriculture has been carried on in places since about 1885, but with varying success. In 1886 and 1887 the crops were fairly good, but in 1889 and 1890 the yield was very small and many of the farmers were reduced to poverty.

The total area in these five counties upon which cereals were raised in 1889 was 54,814 acres. Of this there were in barley and buckwheat 423 acres, in Indian corn 43,819 acres, having an average yield of 5.96 bushels per acre, in oats 4,016 acres, in rye 617 acres, and in wheat 5,939 acres, with an average yield of 6.50 bushels per acre. The losses incurred during the years of drought have called attention to the necessity of providing means of irrigation and a number of projects have been undertaken, the principal source of water supply for this part of the state being the North Platte (*a*), a large river, discharging many times as much water as the South Platte.

Even during the dryest part of the year the amount of water in the North Platte appears to be sufficiently great to supply canals of considerable size, and when irrigation has been thoroughly developed it is probable that the available water supply will be somewhat increased by seepage. Beginning at a point in Wyoming above the state line, and extending down through the counties above named, there are many localities favorable for the diversion of water. A number of irrigating ditches and canals have already been built, a few of these being in size comparable to those near the head of the South Platte. Surveys have also been made for great systems of irrigation, for whose construction millions of dollars would be required. The amount of land irrigated in 1889 is almost insignificant in comparison with the area later brought under ditch. In Scotts Bluff county the development has been especially rapid, although Cheyenne and Deuel counties are receiving their share of attention.

Water is diverted mainly upon the valley land along the river. This is bounded by bluffs, in places rising to a height of several hundred feet, rendering it almost impossible to bring water upon the higher plains or plateaus between the streams. The soil on these higher lands is reputed to be better than that in the valleys, since it is less sandy and comparatively free from alkali. If canals succeed in bringing water to this height large areas, embracing thousands of acres of rich soil, can be watered.

Through Scotts Bluff county probably the greater part of the irrigation is carried on along the north side of the stream, where the topography is in places more favorable for the construction of ditches than on the south side. As the river is very shallow and the sand drifts into the headworks, it is usually a matter of difficulty and expense to keep the water flowing into the ditches. Experiments have been made with the use of steam vacuum pumps to raise water, but the expense of running these has been found in many instances to be too great to be profitable. On the bottom lands from the Wyoming line easterly a number of farmers' ditches have been constructed and several large canals projected. The principal ditches are, on the north side, the Farmers, Enterprise, Winter Creek, Minatare, Alliance, Brown Creek, and Lee Creek, and on the south side the Laramie and Scotts Bluff, Mitchell, Castle Rock, Chimney Rock, Belmont, Empire and Logan.

The Farmers canal heads on the north side of the river, 1 mile east of the state line. If constructed as projected it will be 75 miles long. Work was begun in the spring of 1888, and water was used to a small extent in 1890. It is 14 feet wide on bottom, 6 feet deep, and is planned to have a grade of slightly over 1 foot per mile. This canal is owned by a corporation, and with the exception of the Minatare is stated to be the only one selling or

---

[a] In 1891 the state engineer of Wyoming made several measurements above the mouth of Laramie river, and in the fall of 1892 the topographers of the United States Geological Survey gauged the river at points in Nebraska. The results of these different measurements are given in the following table:

GAUGINGS OF NORTH PLATTE RIVER.

DATES.	Locality.	Drainage area in square miles.	Discharge in second-feet.
June 3, 1891	Douglas, Wyoming	14,665	10,130
October 13, 1891	Fairbanks, Wyoming	16,775	579
November 5, 1892	Douglas, Wyoming	14,665	595
December 4, 1891	Douglas, Wyoming	14,665	807
September 14, 1892	North Platte, Nebraska	28,250	770
October 8, 1892	Camp Clarke, Nebraska	25,267	335
November 2, 1892	North Platte, Nebraska	28,250	1,070
November 22, 1892	North Platte, Nebraska	28,250	1,370

Fairbanks is some 50 miles or more below Douglas and about 12 miles above the mouth of Laramie river. The town of North Platte, Neb., is near and between the junction of the North and South Platte rivers, and Camp Clarke is about halfway between Fort Douglas, Wyo., and the town of North Platte.

renting water rights. Enterprise ditch heads 5 miles east of the state line and covers land between the Farmers canal and the river. It is 20 miles in length, and in its course is reported to cover about 8,000 acres.

Winter Creek canal heads at a point nearly north of Gering, covering in turn land under the Enterprise canal. It is 14 miles long, 16 feet wide on bottom for the first 2 miles, then narrowing to 12 feet wide for the remainder of the distance. Stock in the canal is divided into 168 shares or water rights, each of these entitling the holder to 26.5 inches of water. The water duty is estimated to be 1 inch per acre. The company owning this ditch was organized in 1888, and the work of construction was carried on so that irrigation was practiced in 1889 and later with fairly successful results. The Minatare canal heads about 5 miles above the town of that name and covers a narrow strip of land along the north bank of the river. It is owned by a corporation composed mainly of farmers. It is about 10 miles long, the bottom width of the main canal being 30 feet and of the branches 14 feet. Work was begun in 1888, and water was turned into the canal in August of that year. The appropriation calls for 864,000 cubic inches of water, whatever this may be. The capital stock of the company is placed at $50,000, and the par value of a share is stated to be $100. Each share represents 40 inches of water. An 80-acre water right has been sold for $200. It is difficult to estimate the actual cost of this work. In order to maintain and keep the ditch in repair there is an assessment of labor and also a cash levy of about $10 per 80 acres to pay the salary of a superintendent. This is one of the first successful canals in this part of the state, and on this account has attracted considerable attention.

The Alliance, Brown Creek, and Lee Creek ditches head in succession down stream, being wholly within Cheyenne county. The Alliance is about 10 miles long, was built by farmers, and is reported to be highly successful. Brown Creek canal heads east of Camp Clarke. The appropriation calls for 10,000 inches of water, and the work, when completed, is to be 12 miles long, 50 feet wide on bottom, and nearly 3 feet in depth. The Lee Creek is a small private ditch 7 miles long, heading near the lower end of Brown Creek ditch.

Taking the canals on the south side of Platte river in order down stream, the first project of importance is the Laramie and Scotts Bluff canal. On this, however, little if any construction work has as yet been done. It is to head in Wyoming, 6 miles west of the Nebraska line, and as planned is to be 80 miles in length. The surveyed line follows along the bottom of the bluffs or hills of the valley and covers all of the available land in Scotts Bluff county between these and the river. The grade for the first 40 miles is planned to be 0.5 feet per mile and from that point 0.75 feet per mile. It is estimated that the area between this and the other irrigation systems is 48,000 acres.

The Mitchell canal heads in Wyoming, 1 mile west of the state line, and on that account possibly enjoys certain advantages over other irrigating systems taking water at lower points in the state of Nebraska. It is 25 miles long and has a fall of 1.5 feet per mile. When measured in the flume over Horse creek the canal was carrying 24 second-feet, at a time of low water. The stock of the company is divided into 370 shares of a par value of $100 each. A share is understood to entitle the owner to the use of 20 inches of water upon 20 acres of land. The cost of a perpetual water right is also given at $7 per acre, or water is rented at the rate of $2 per acre. The annual cash assessment has been $3.10 per share, together with a work assessment of 2 days' labor per share. Construction work was begun in the fall of 1890, and water was used in the latter part of the following year in order to wet the ground for the following season. The canal is reported to cover 17,000 acres, and assuming that the cost of construction was, as estimated, $34,000, the average first cost of irrigation would be only $2 per acre. The cost of the preparation of the land for cultivation was also estimated to be $2 per acre, an amount lower than in other parts of this district. In comparison with this the land under the canal is stated to be worth $15 per acre and upward. The Central is a small ditch heading near Gering and covering a small area near the town. It is about 4 miles long and is used both for irrigation and milling purposes.

The Castle Rock canal heads about 4 miles east of Gering and extends along the south side of the river for about 17 miles. The bottom width is 16 feet, and the cost is stated to have been upward of $1,000 per mile. Along the course of the ditch is one flume 200 feet in length, but otherwise the work is comparatively simple. The ownership is in shares of $100 each, and the water rights are fixed at 40 inches for 40 acres. The irrigation works commonly known as the Chimney Rock take water from the south side of the North Platte river about a mile west of the Cheyenne county line and 12 miles west of Camp Clarke. The main ditch is 10 miles long, and has a fall of 1.66 feet per mile. It has been built by farmers, and the cost can not be ascertained. Work was begun in 1889, a little irrigation being done in the following year. The crops irrigated are wheat, oats, corn, barley, and flax.

The Belmont Irrigating Canal and Water Power Company has constructed a canal 32 miles long, 40 feet wide on bottom at head, 3 feet deep, and with a grade of 2.6 feet per mile. The head is 4 miles west of Camp Clarke, the canal leaving the river and following along the upper edge of the bottom lands. The notice of appropriation was filed in December, 1889, and construction work was begun in the following year. It covers 26,000 acres, making the average cost of construction $4.75 per acre. A considerable acreage under this canal was devoted to the cultivation of flax, and the yield, 14 bushels to the acre, was considered to be a success. Twenty inches constitute a water right, or water is rented at $2 per acre.

The Empire is a small ditch, heading a short distance below the Belmont, and covering land under that canal. It is 6 miles long, 3 feet wide, and the cost was very low, probably not more than from $1 to $2 per acre covered. The Logan is another small private ditch, about 2.5 miles long, irrigating a small strip along the river bank.

Away from the North Platte a small amount of water is obtained from Lodgepole and other creeks, and also from springs and wells. The wells are usually from 150 to 300 feet in depth, and when complete, including windmill and tank, cost from $300 to $500. The amount of water obtained is large and the supply can rarely be exhausted by windmills. Springs are found in many localities, and the water sometimes forms ponds of considerable size, finally escaping by evaporation. In the northern end of Deuel county the lakes are especially numerous, the waters from some of these probably escaping into Blue river, which flows southerly into the North Platte. In the valleys along Pumpkinseed creek and Lodgepole creek are a number of small private ditches, irrigating gardens, trees, and small areas of field crops, the water being utilized as far as possible without water storage. Lodgepole creek flows from the Laramie hills in Wyoming easterly across the plains, its water usually disappearing into the sandy soil. At places, however, it appears on the surface during a part of the year at least, and can be diverted for irrigation. After crossing the state line into Nebraska the creek furnishes water for several ditches, each taking out apparently all of the water at the point of diversion. As an example of these ditches, may be given that of the North Side Irrigating and Milling Company, heading about 8 miles west of Kimball. It is 4.5 miles long, averages 8 feet in width, and cost $300. It was begun in 1889 and first used in 1890. The cost of water is stated to be about $1 an acre each season.

KEITH, LINCOLN, AND COUNTIES TO THE NORTH.

Keith and Lincoln counties lie northeasterly from Colorado, a corner of the first being adjacent to Sedgwick county, Colorado. Both the North and South Platte flow easterly through Keith county at an average of about 5 miles apart, finally uniting their waters in the eastern half of Lincoln county. To the north are 2 tiers of counties, the first tier containing Arthur, McPherson, and Logan counties, and above these Grant, Hooker, and Thomas. Cherry county, whose area is greater than that of the 6 just mentioned, includes the lands to the South Dakota line and adjoins Sheridan county, which lies on the west. Throughout these 9 counties agriculture is carried on in favorable localities, stock raising, however, being the principal industry. In Keith and Lincoln counties 84,596 acres of cereals were raised in 1889, of this amount 58,421 acres being in Indian corn, with an average production of 22.94 bushels per acre, and 14,102 acres in wheat, averaging 12.06 bushels per acre. In the 7 remaining counties the total area of cereals was 57,578 acres, and of this there were in Indian corn 46,449 acres, producing on an average 17.20 bushels per acre. The experience of several years has convinced the farmers that greater success can be attained only by irrigation.

The Niobrara river, which flows from Sheridan county across the northern end of Cherry county, furnishes a perennial supply of water, the quantity not varying greatly throughout the year. It flows through a narrow valley, canyon like in character, with little if any irrigable land along this part of its course. South of this stream are the North Loup, the Middle Loup, and Dismal river, its principal tributary. All of these streams receive their water from springs, and their discharge, like that of the Niobrara, fluctuates within narrow limits. It is stated that even in the driest weather the rivers do not fall perceptibly, and that after a rain they rarely rise more than a foot or so. The country drained by these streams consists largely of wind sculptured sand hills rising to heights of from 10 to 200 feet and inclosing small valleys. The bottoms of some of these valleys are wet and crops of hay can be cut. The grazing on the sand hills is good, and the springs and lakes furnish water sufficient for the needs of cattle.

The South Loup, rising in Logan county, is less regular in its behavior than the streams named above. It occasionally becomes nearly or quite dry in summer down to the point where it unites with other tributaries. Its waters have been used to a small extent for the irrigation of kitchen gardens and trees. The wells throughout this area are usually from 150 to 300 feet in depth, and, wherever the owner has sufficient means, are pumped by windmills. On the high table-lands between the streams mentioned above are large areas of fertile soil, which would be very productive if water could be had. There does not seem to be any means of securing the needed supply, except in a few localities, by storage of storm waters or by pumping from wells.

Agricultural development of this part of the state by means of irrigation must of necessity be confined to the vicinity of the North Platte. Already a number of ditches, both in Keith and Lincoln counties, have been constructed and others are projected. Besides the river, there are a number of creeks coming from the sand hills north of the river in Deuel and Keith counties which could be made to serve a considerable acreage of land on the north side of Platte valley. The poor crops of 1889 and 1890 stimulated the building of irrigation works. Among the most important of the side streams useful for irrigation are Blue and Birdwood creeks, the former in Deuel county, and the latter about 60 miles below in Keith county.

Blue creek is about 30 miles in length, and, rising in springs among the sand hills, flows southwesterly and southerly into the North Platte. The volume of water carried, as in most of these streams from the sand hills, is remarkably uniform throughout the year, excepting in times of heavy rains, when the flow is somewhat increased.

The discharge, when measured, amounted to 105 second-feet. It heads in what is locally known as the lake region, a country dotted by lakes, some fresh, others alkaline. Along its valley are lands adapted to irrigation, but only one small ditch has been constructed, this being on the west side about 3 miles above the mouth of the creek. A larger ditch could be taken out farther up the creek, covering a considerable area of land in the valley and on the Platte bottoms.

The valley of Platte river eastward from Blue creek has a large and well distributed water supply. Numerous streams discharging from 3 to 5 second-feet during the summer come from the sand hills and have a fall sufficiently great to allow of taking their waters to almost any point desired. Along Otter creek are a few small ditches, aggregating about 4 miles in length, and also along White Tail creek is a ditch which irrigates lands in the open valley. Most of the water of these ditches is used in the production of hay, which, when loaded, is valued at from $7.50 to $9 per ton.

Birdwood creek is probably the largest tributary of the North Platte in western Nebraska. When measured in September it was discharging at the rate of 126 second-feet, the flow not fluctuating greatly throughout the year. Near the junction of the east and west forks, and about 10 miles above the mouth of the creek, work has been begun on a ditch presumably for the purpose of irrigating some of the land now used for grazing. The valley of the creek is, however, narrow, the principal body of irrigable land being near the mouth.

On the south side of the North Platte river, about 3 miles above the mouth of Birdwood creek, is the head of the North Platte canal, covering land between the North and South rivers. The total length of the canal is 23 miles, the average width 16 feet, and the cost is stated to have been $40,000, the laterals being built by farmers at their own expense. Water is diverted by means of a wing dam built of timber and having a length of 1,550 feet. The canal is owned by a corporation, which has sold perpetual water rights at the rate of $6.25 per acre. The annual assessments are not to exceed $10 for 80 acres. The unit of distribution is 1.44 second-feet per 80 acres. This is claimed to be the pioneer ditch of the region, being first used in 1885.

During the summer the South Platte is often dry, and its surface flow can not therefore be depended upon for purposes of irrigation. In the fall the water gradually begins to flow again, and by November the discharge reaches several hundred second-feet. Three measurements of the amount in the stream were made by topographers of the United States Geological Survey shortly after the fall rains. In October the discharge at Julesburg, Colo., was 653 second feet, in early November at the bridge south of the town of North Platte 460 second-feet, and late in November at the same point 645 second-feet. The bed of the stream is very broad, and during the summer after the disappearance of the flowing water the sandy channel, as well as the adjacent low land, remains saturated to within a short distance of the surface. Attempts have been made to draw upon the water thus stored in these pervious beds under or adjacent to the river channel, bringing it out by means of ditches built at a less grade than that of the stream, in order to utilize this during the months of July, August, and September. One of these projects, built by the Ogallala Water Power and Irrigation Company, heads about 10 miles above Ogallala, on the north side of the stream. The ditch is 12 miles long, about 10 feet wide, 1.5 feet deep, and has a grade of 1.5 feet per mile. It empties into a small reservoir covering about 20 acres, and located 1.5 miles northwest of the town. At the head of the ditch is a box culvert 10 feet wide, 3 feet deep, extending for about one-fourth of a mile up the river parallel to the bank, its upper end opening to receive the water whenever there is any in the channel. During the summer, when the bed is dry, it is expected to obtain water by means of an open ditch dug in the bed of the stream extending another fourth of a mile above this culvert. Water seeps into this ditch and culvert and is also collected by means of a small drain or channel extending from the head of the main ditch diagonally across the bed of the river. On October 1 there was found to be about 2 second-feet thus obtained, and at a point 3 miles below the headworks this little stream had increased to nearly 3 second-feet. The drainage channel was first constructed in 1890 during the great drought, but the amount of water obtained at that time was less than had been anticipated. The canal was built by a corporation, but the county, or rather Ogallala precinct, voted to issue bonds to the amount of $35,000 to aid in the work. Little, if any, water has been used for irrigation, and the project is not generally considered as successful.

On the south side of the river is what is known as the Hollingsworth ditch, owned by the South Side Irrigation and Water Power Company. It is about 9 miles long and averages 4 feet in width. It carries water only in times of flood, being used to some extent for irrigation in the early part of the year. When constructed it was supposed that a large perennial supply could be obtained from the ground water saturating the pervious beds of the valley, but as a result of experiments in other localities less confidence has been placed in this.

Along the Platte river east of the junction of the north and south branches are several small ditches and also 2 canals of notable size, both of these being on the north bank. They were constructed, however, mainly for the purpose of obtaining water power, little, if any, of the water being employed in irrigation. The first of these is the Gothenburg canal, in Lincoln county, and east of this the Kearney canal, in Buffalo county. The head of the former is near Brady island, from which point it continues easterly for about 9 miles, swinging back from the river and gradually mounting the lower bluffs to a point north of and above the town of Gothenburg, where it empties into a reservoir. From this the water is taken in large pipes to supply turbines, which in turn furnish power to dynamos. The system, as well as that at Kearney, furnishes an excellent example of the utilization of water power under what would at first appear to be unfavorable circumstances. In the case of this canal also it was hoped that the summer water supply could be augmented or rendered more constant by drawing upon the ground water, and at the head long trenches were constructed through the marshes and low lands in order to bring out this accumulated water. Tests were also made above the head of the canal in the old river bed of the Platte, and the engineer in charge states that after passing through 15 feet of sand and gravel a hard clayey layer 4 feet in thickness was reached; below this in turn were found sand and gravel, the water in the latter rising to the height of that in the upper layers. Similar trials were made for a distance of 1.5 miles up stream, all giving the same result.

The Kearney canal is of interest more from the side of water power than from that of irrigation. The head is in the vicinity of Elm creek, and from that point it extends easterly for about 15 miles to a reservoir near town. Water is taken directly from the river, and during the summer the various rivulets flowing in the broad sandy channel are brought together and forced over to the north bank by means of a temporary obstruction of sods and sand laid diagonally up stream. Large amounts of money have been spent in excavating and making long trenches in the sands and gravels of the bottom lands. It is claimed that this work was at least partially successful, but apparently this part of the project has been abandoned. In addition to the canals built or projected to take water from Platte river, plans have been made for utilizing the supply in the forks of the Loup river; for example, to cover lands near Brokenbow, in Custer county, and the town of Loup, in Sherman county. Both of these points are east of the one hundredth meridian, which for convenience has been assumed to be the eastern boundary of the irrigated region.

SOUTHWESTERN COUNTIES.

The counties of Perkins, Chase, Hayes, Frontier, Dundy, Hitchcock, and Redwillow are in the southwestern corner of Nebraska, east of Colorado. They lie mainly within the drainage basin of the Republican river, which flows in an easterly direction along the southern boundary of the state. During the census year irrigation was practiced to a very small extent, and at that time most of the farmers indignantly denied that it was necessary. It was only after the unusually severe drought of 1890 that the majority gave up hopes of making a success of "dry farming". The serious losses of crops and the poverty prevailing at that time among the farmers caused many to leave this part of the state, while those who remained eagerly discussed the possibilities of irrigation, the few small ditches already constructed having proved the success of this method of agriculture.

The surface of this part of the state as a whole falls from the Platte river southward toward the Republican, and this, combined with the general easterly slope of the plains, gives the diagonal, southeasterly trend to these streams and allows their head waters to approach to within a few miles of the Platte. It is stated in the report by Samuel Aughey on the physical geography of Nebraska that the Republican receives by seepage a portion of the waters of the Platte. It is probable, however, that the rainfall upon the pervious beds of this part of the state will fully account for the presence of springs supplying the tributaries of the Republican. On the divide between the Platte and the Republican and the numerous tributaries of the latter stream the soil is unusually fertile, and with sufficient rain produces largely. Many farmers state, however, that during 4 or 5 years they have not been able to raise a fair crop, and one person writes that the average yield per acre for 10 years in succession has not been one-third of that in the eastern part of the state. In these 7 counties in 1889 cereals were raised on 406,720 acres, Frontier county containing the greatest area, namely, 101,026 acres. Taking the counties together, there were in barley and buckwheat 1,533 acres, in Indian corn 277,337 acres, averaging 19.65 bushels per acre, in oats 43,473 acres, in rye 12,030 acres, and in wheat 72,347 acres, averaging 11.17 bushels per acre.

The principal water supply of this area is derived from Frenchman creek, which rises in Phillips county, Colorado, flowing easterly through Chase and Hayes counties into Hitchcock county, where it joins the Republican. This creek flows throughout the year without great fluctuations. The Republican river, on the other hand, has been nearly or quite dry during the summer, in that of 1890 no water appearing in the bed, although the sands and gravels beneath the surface remain saturated. In this year construction was begun on a number of canals designed to take water from both of these streams and to carry it out upon the valley lands. The soil of the divides between the rivers might be made fertile as well as that of the lower irrigable ground, but the elevation is too great to render it profitable to conduct the comparatively limited water supply the required distance. The wells on the higher ground are from 100 to 300 feet in depth, depending upon the elevation, water being found at approximately the level of that in the valley streams.

In Chase and Hayes counties ditches have been taken out from the Frenchman and its principal tributary, and farther down the stream are canals covering land in the vicinity of Culbertson. On the Republican are ditches at short intervals from near Wray, in Yuma county, Colorado, taking water out in the vicinity of Haigler, Benkleman, Trenton, Culbertson, McCook, and Cambridge. Apparently some of these have been projected with little regard to the amount of water available, and it is only a question of a short time when, during the dry seasons, there will be a deficiency and only a portion of the land under ditches can be watered. In the case of many of the new canals dependence is being placed upon the water which remains saturating the sands of the river bed after the stream has dried. The amount of water in these sands, as previously stated, is apparently inexhaustible by ordinary methods of pumping, but for the needs of several irrigating canals it is small. One of the earliest systems of irrigation is the canal of the Haigler Land and Canal Company (formerly the Farmers Colorado and Nebraska Ditch Company), which takes water from the south side of the north fork of the Republican river near the town of Laird, Colo. It is 13 miles long, averages about 8 feet in width, and cost $5,000. Farther east, near the town of Benkleman, are what are known as the Porter ditches, and farther down, near Culbertson, are the works of the Culbertson Irrigation and Water Power Company and of the Cambridge and Arapahoe Irrigation Company, both of these being on the north side of the creek. On the south side of the Republican are the Farmers, Trenton, and Meeker ditches.

The Culbertson canal was begun in 1890, and was planned to be 80 miles in length, 32 feet in width near the head, and to cost $170,000. It is estimated that a supply of 400 second-feet can be obtained, and that the lands can be irrigated at the rate of 200 acres to the second-foot. The Meeker ditch heads at the junction of Frenchman creek and Republican river, south of the town of Culbertson, and from this point continues easterly, covering land south of the river to and beyond McCook. The line as surveyed extends to a point southeasterly from Cambridge, and then swings back from the river to the vicinity of Wilsonville. The amount of water available from the river seems hardly sufficient to supply such a long canal. So far as known, systematic records of the amount of water in these streams have not been kept. Two gangings, however, were made, showing that the discharge of Frenchman creek in late November was 177 second-feet, and of Republican river above Frenchman creek 209 second-feet. These measurements were made after several days of heavy rains and snow storms, and the quantity of water was greater than during the summer. Judging from the statements of the residents of this locality, the average summer discharge of Frenchman creek is somewhat less than 175 second-feet, and the Republican above this junction possibly discharges about 200 second-feet throughout the winter, the quantity fluctuating widely on account of the irregular floods.

ARTESIAN WELLS.

These wells are principally in the northeastern part of the state, the largest number being in Knox, Cedar, and Dixon counties, on the south side of the Missouri river, opposite Clay and Yankton counties, in South Dakota. There are also a number of shallow wells in the valley of the Elkhorn river, in the southern half of Holt county, about 75 miles southwesterly from the group first mentioned. There are also reported to be a few shallow flowing wells in Seward county, about 30 miles west of Lincoln, the capital of the state. The wells in Cedar and adjoining counties probably receive their water supply from the Dakota sandstone, this being the southern end of the developed artesian area, while the small flowing wells of Holt and Seward counties obtain water from gravels of comparatively recent origin.

In Knox county, at the Santee agency, a well has been drilled to the depth of 604 feet, at a cost of $1,500, the discharge, however, being only 6 gallons per minute. This small amount is accounted for, in part, by the statement that the well is on high ground. The small wells nearer the Missouri river discharge more freely. In Cedar county a large number of wells have been put down in Bow valley and near the Missouri river, these being mainly employed for watering cattle. Little if any of the water has been used for irrigation. Some of the wells have stopped flowing, clogged by sand, or the leakage through the casing is so great that none of the water reaches the surface. In Dixon county the wells are on the bottom lands, near Newcastle. Irrigation has never been tried, although the water is reported to be good, and the excess in a few instances is used for fish ponds.

In Holt county the flowing wells consist simply of a pipe from 1.25 to 2 inches in diameter, driven through the clays, sands, and gravels to a depth of from 50 to 185 feet, or until an ample supply of water is found. The water, which is clear and cold, usually rises to the surface, or even to a height of 5 feet or more above. The temperature is probably too low for the water to be used immediately for irrigation, even if it were desirable to do so. These wells cost, on an average, $48, and can be obtained almost anywhere on the low ground. A deep well 6 inches in diameter has been started at O'Neil, the county seat, the intention being to drill down to the Dakota sandstone, and a depth of about 1,450 feet has been reached. Water, if obtained sufficiently pure and in large quantities, will be used for city purposes.

The wells in Seward county reported to be flowing are at Beaver Crossing. They are very shallow and have been put down for the purpose of obtaining water for stock. East of this locality, at the city of Lincoln, a well has been drilled to the depth of 985 feet, obtaining a large amount of water at various depths, some of this being strongly saline. Still farther to the east, in Otoe and Nemaha counties, which border on the Missouri river, are several borings from which salt water flows. At Unadilla a salt well 280 feet in depth discharges at the rate of 32 gallons an hour. South of Lincoln, in Gage county, a well at Beatrice has been drilled to the depth of 1,200 feet, but without success.

Throughout central and western Nebraska no flowing wells, with possibly one or two exceptions, have been found. Water for domestic purposes and for watering cattle, as a rule, can be obtained only by drilling to a depth of from 100 to 200 feet, windmills being used to raise it to the surface. In many places springs abound, but these, compared to the needs of the people, are very small and widely scattered. In Boxbutte, Cherry, Cheyenne, and neighboring counties, in the northwestern part of the state, the common wells are reported to be from 35 to 250 feet in depth, and in Deuel county from 140 to 300 feet. In Frontier county, toward the southwestern part of the state, it is stated that water is very scarce, and that the wells, which are upward of 300 feet in depth, are often pumped dry in from 1 to 2 hours. In Custer and Dawson counties, about the center of the state, the wells, notably on the high ground, are 300 or even 400 feet in depth, costing about $1 per foot. None of these, except possibly one or two on the bottom lands, discharge any water. In McPherson county one small well, 28 feet in depth, is reported to discharge a small amount.

KANSAS.

In Kansas, as in Nebraska, the counties are discussed in groups according to geographic position, those in the northern part of the state being considered first and then the group next adjoining on the south. In the 32 counties in the western end of the state in 1889 there were raised 775,753 acres of cereals, the greater part, namely, 523,030 acres, being in Indian corn, the average yield of which was 13.43 bushels per acre, or about one-third the average for the whole state. Second in importance to this was wheat, there being 126,247 acres, averaging 10.23 bushels per acre, while the average yield of the state was 19.21 bushels per acre. The area irrigated is almost insignificant, it being only 2.68 per cent of the acreage producing cereals.

NUMBER OF IRRIGATORS, AREA IRRIGATED, AND AVERAGE SIZE OF IRRIGATED FARMS IN KANSAS IN 1889.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.	COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.
Total	519	20,818	40	Kiowa	5	15	3
				Lane	4	48	12
Cheyenne	6	539	90	Logan	9	112	12
Clark	2	550	275	Meade	25	603	24
Decatur	10	248	25	Norton	4	27	7
Finney	162	9,151	56	Pawnee	6	92	15
Ford	116	1,807	16	Rawlins	16	323	20
Gove	3	9	3	Scott	3	24	8
Graham	14	202	14	Seward	3	146	49
Gray	4	266	67	Sheridan	7	23	3
Hamilton	8	1,130	141	Wallace	13	206	16
Hodgeman	6	70	12	Wichita	2	9	5
Kearny	91	5,218	57				

NORTHWESTERN COUNTIES.

Cheyenne, Rawlins, Decatur, Norton, Sherman, Thomas, Sheridan, and Graham counties in the northwestern corner of Kansas are drained for the most part by tributaries of the Republican and Solomon rivers, both of which streams flow easterly and then southeasterly into the Kansas river. Springs flowing throughout the year furnish water to these streams, keeping up a nearly constant supply near the head waters. At some distance below the springs the streams dwindle during the hot weather to a mere thread, and a few of the minor tributaries become dry. A small amount of irrigation has been successfully carried on, as shown by the table above, the water being diverted by a few ditches. The method of applying water more commonly in use in this part of the state is what is known as subirrigation. Dams are built across the small streams, holding the water until it backs up and covers the bottoms, in this way completely saturating the ground, and by percolation moistening a large area of low land in the vicinity. The principal streams employed in irrigation are the south fork of the Republican, Beaver, Sappa, and Prairie Dog creeks, and the north and south forks of Solomon river.

In these 8 counties cereals were raised in 1889 on 534,445 acres. Of this there were in barley and buckwheat 1,126 acres, in Indian corn 374,501 acres, producing on an average 15.68 bushels per acre, in oats 40,379 acres, in rye 36,693 acres, in wheat 81,746 acres, averaging 10.28 bushels per acre. Some of the farmers state that for many years in succession, owing to the deficiency and irregularity of rain, they have not been able to raise a profitable crop, although the soil is remarkably fertile. On account of failures of crops many farms have passed into the hands of loan and trust companies, the owners not being able to pay the interest. The hope of ultimately irrigating the land has prevented many of the farmers from leaving the country.

The rain storms on this level country are often violent, and are therefore not as efficient in wetting the soil as longer and more gentle showers. The country as a whole consists of rolling prairie, but slightly cut by the creeks, and even where too dry for cultivation it is valuable for stock raising. Water is brought to the surface by means of windmills, from wells of from 50 to 250 feet in depth, and is utilized mainly in watering cattle, a few gardens only being irrigated in this manner. Above St. Francis, in Cheyenne county, is the ditch system, known as the Emerson, taking water from the south fork of the Republican river, the head being near the state line. These ditches are to be continued along the southeastern side of the river, down to St. Francis, passing by one or two reservoirs in which surplus water can be stored for use in time of need. Under these is a ditch known as the Benkleman, heading about 5 miles lower down, and keeping nearer the river.

WEST CENTRAL COUNTIES.

Wallace, Logan, Gove, Trego, Greeley, Wichita, Scott, Lane, Ness, Garfield, and Hodgeman counties include the central portion of western Kansas lying north of counties traversed by the Arkansas river. As in the case of the region farther to the north, small areas scattered through this region are irrigated by water obtained from springs or small creeks formed by springs, or in a few cases by pumping from deep wells. The suppply is not sufficient for general irrigation, but it has enabled experiments to be made in many localities demonstrating the value of artificial watering. The counties lie within the drainage basins of the Saline and Smoky Hill rivers, both of which flow easterly into the Kansas river, and on the south include part of the head waters of Walnut creek and Pawnee fork, flowing into the Arkansas. These streams receive most of their water from springs discharging throughout the year almost without change. During the summer season the creeks shrink to insignificant proportions, and without some method of holding water they are of little importance in irrigation. By diverting the water, near the points where it issues from the ground, and using it before much of it has time to evaporate a larger acreage can be watered than at lower points.

The rainfall is exceedingly irregular, and even if there happens to be plenty for part of the crop at least there is liability of loss by the hot winds occurring in July and August. Some of the farmers state that they have tried year after year, but have not succeeded in raising a profitable crop. They have lost nearly all their possessions in attempting to farm and only remain through hopes of the introduction of irrigation. The total area upon which cereals were raised in 1889 in these 11 counties was 132,426 acres. Of this there were in barley and buckwheat 364 acres, in Indian corn 77,106 acres, averaging 6.84 bushels per acre, in oats 10,145 acres, in rye 15,514 acres, and in wheat 29,297 acres, averaging 11.62 bushels per acre. The total population was 26,014.

The greater part of this area is a gently undulating plain cut in a few places by ravines, or draws, as they are locally called. The surface of the soil is in most places so packed by the tramping of animals that it seems to be impervious. Below this and extending to depths of from 50 to 100 feet or more is a porous material resting upon beds of sand or gravel. This latter deposit is saturated with water, and to ordinary pumping machinery the supply seems almost inexhaustible. Hopes have been entertained that by suitable machinery some of this water can be brought to the surface at a cost so low that it can be profitably used in irrigation. Attempts have been made to secure artesian wells, but unfortunately without success. At Jetmore, Hodgeman county, a hole has been drilled to the depth of 1,000 feet without obtaining flowing water, and at Larned, Pawnee county, salt water has been struck. Water is diverted by means of ditches from Beaver or Ladder creek, from Rose creek near Wallace, and from a number of other streams. Most of these are very short, only about a mile in length. Among the most important of these ditches is that belonging to the Elkader Water Power and Irrigation Company, taking water from Beaver creek. It is 3 miles long and about 3 feet wide. It was begun in 1888 and it was used to a small extent in 1890.

COUNTIES ALONG ARKANSAS RIVER.

Hamilton, Kearny, Finney, Gray, and Ford counties are traversed by the Arkansas river, which flows in a general easterly course from Colorado. Water for irrigation is diverted from this river by means of several large canals, heading in succession from a point near Syracuse down to and beyond Dodge. This stream is about the only source of supply, except in the case of wells from which water is pumped to irrigate a few acres.

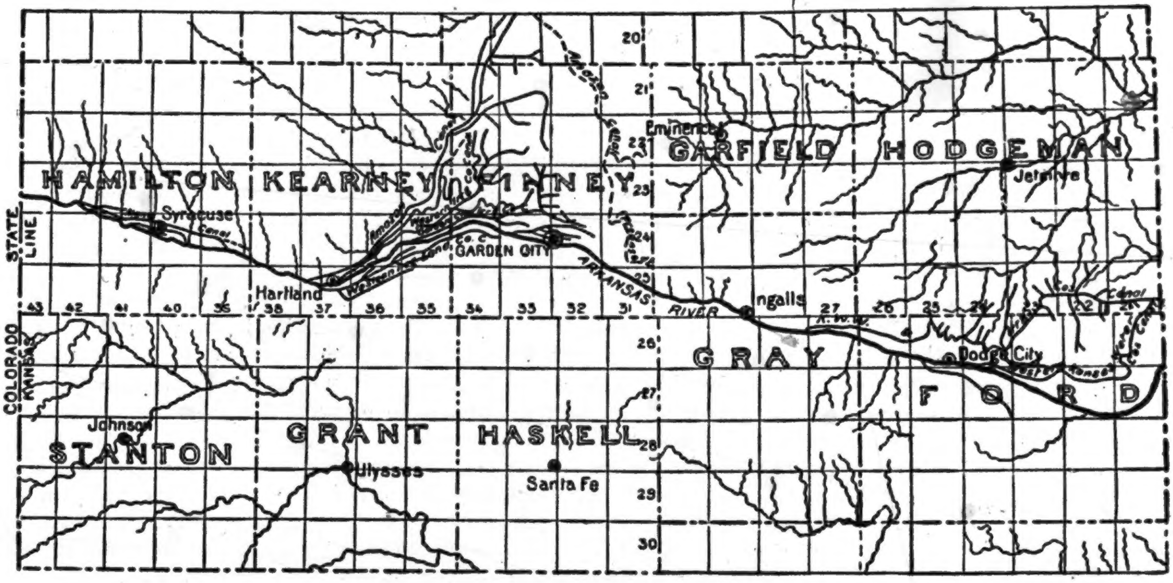
Agriculture without irrigation has been attempted in many localities in these counties, but the results have been so discouraging that many farmers have abandoned their homes and with their few movable possessions have gone to other states. The soil on the plains, especially to the north of the river, is fertile, and the climate is favorable to agriculture in all respects except that of moisture. Although many attempts at farming have been made by persons from various parts of the United States and Europe, having all degrees of skill, comparatively few have prospered, the most successful persons being those engaged in raising cattle, the buffalo grass furnishing excellent grazing. The total area upon which cereals were raised in these 5 counties in 1889 was 51,587 acres. Of this there were in barley 410 acres, in Indian corn 33,009 acres, averaging 9.22 bushels per acre, in oats 10,002 acres, in rye 3,056, and in wheat 5,110 acres, averaging 8.60 bushels per acre.

The soil on the so-called table lands or plains is superior to that in the valley of the Arkansas, this latter being more or less sandy and occasionally impregnated with alkaline salts, but the higher land can not be brought under irrigation except to a small degree by long canal lines or by storage reservoirs. Water for domestic use is obtained by means of wells of from 30 to 300 feet in depth. Some of these are pumped by windmills, but the supply obtained by this means is too small for the irrigation of more than a few acres.

In 1889 a preliminary line was run by engineers of the United States Geological Survey to determine the possibility of diverting the water of the Arkansas upon the high lands in Hamilton and Finney counties. This survey, starting about 10 miles west of the Kansas-Colorado line, followed along the north side of the river, the line passing about 4 miles north of Syracuse and 8 miles north of Kendall. It then turned and passed northerly across the high land. This work showed that if water could be stored in sufficient quantities to supply all the canals it would be possible to bring under irrigation a large part of the land in the counties north of and adjoining the Arkansas in western Kansas. In short, the amount of land which can be watered is only limited by the available supply.

The Arkansas river, although having a large drainage area, is a somewhat unsatisfactory stream for purposes of irrigation. The greater part of the water is diverted for use in Colorado long before the stream reaches the Kansas line, and the channel of the river in the counties named above is occasionally dry, the duration of drought being apparently longer in the lower counties than in those up stream. During June and into July there is usually a period of high water, during which the canals can be filled. There has been general complaint among the farmers regarding the irregularity of water supply and of the methods of canal control. Some of the canals were built with the intention of obtaining a supply of water from what has been termed the "underflow", or water saturating the permeable beds of sand and gravel under or adjacent to the river. The amount of water thus obtained has been too small to repay the outlay. Added to this the fact that many of the farmers are not skilled in irrigation, it results that there is more or less dissatisfaction, intensified by the too sanguine hopes of great benefits to be received from this method of agriculture. The annual cost of water and the uncertainty of obtaining it each year have deterred many farmers under the canals from attempting to irrigate. Those, however, who have received a sufficient supply and have used it to advantage have prospered.

MAP OF IRRIGATING CANALS ALONG ARKANSAS RIVER IN WESTERN PART OF KANSAS.



The principal canals in order from the Colorado line easterly are on the north side of the river, the Alamo, Amazon, Southwestern, Kansas, Garden City, Eureka, and Pawnee canals, and on the south the Western canal and South Dodge. The Alamo canals take water out on the north side of the Arkansas river, canal No. 1 heading about 6 miles below Coolidge and canal No. 2 about 5 miles lower down, being above Syracuse. Both of these flow in a general parallel course to and beyond Syracuse. The total length is 20 miles, the average width 15 feet, and the total cost was $17,000. The canals were begun in 1888 and used to a small extent in the succeeding year. The company does not sell water rights, but delivers the water each year for about $1.50 per acre.

The Amazon canal of the Syndicate Lands and Irrigation Company was projected to take water from below the bed of the river by means of a deep trench heading about 3 miles above Hartland in Kearny county, the canal continuing to a length of upwards of 100 miles. Water first used from the canal was diverted from the river by means of a temporary wing dam of sods, the permanent inlet not having been constructed. No perpetual water rights are sold, but the charge for water has been $2 an acre.

The Southwestern canal, owned by the Southwestern Irrigation Company, heads about a mile above Hartland, Kearny county, and follows along the river on the north side in a general northeasterly direction. It is 40 miles long and 20 feet wide. Below this are the Kansas and Garden City canals, both belonging to the Garden City Irrigation Company. The length of the first is 20 miles and the average width 16 feet, and the length of the second is 12 miles and width about 12 feet. Both of these cover land in the vicinity of Garden City. Water is delivered to the land at the rate of $1.25 per acre, no rights being sold. Under many of these canals there has been considerable difficulty in persuading the farmers to use the water in a proper way or even to employ it at all, and as a rule more water has been turned on to the fields than can be properly used.

The canal of the Kansas Water Works and Irrigation Company, formerly known as the Eureka, takes water from a trench on the north side of the Arkansas, west of Ingalls, Gray county. The total length of the canal is 96 miles, the average width 30 feet, depth about 4 feet, and the cost is stated to have been $2,000,000. It was begun in 1884, used in 1887, and finished in 1889. The first 40 miles consist of a series of heavy cuttings in rock and earth, no flumes being used. The grade of this part of the canal is about 20 inches to the mile, while the average fall of the Arkansas river here is 7 feet per mile. Thus in the neighborhood of Dodge the canal has attained a height of about 100 feet above the river, and, having reached the top of the bluffs, continues to Spearville and Kinsley, being for the greater part of the way on a low table-land or plateau, where the topography is such that water can be taken out by laterals on each side. The canal is owned by a corporation, which sells water to farmers, water rights being valued at $15 per acre, subject to an annual assessment of $1 per acre. It is considered that 1 miner's inch per acre under a 4-inch pressure is sufficient.

It was the original intention to divert water by means of a dam in the Arkansas, but the structure built for this purpose was washed away by a flood in 1890. This attempt having failed, a trench, known as the gathering channel, was excavated parallel to the river at a depth of about 10 feet below the level of the stream and for a length of nearly 2 miles. It is proposed to lift water from this gathering channel or reservoir into the canal by means of four centrifugal pumps, each capable of delivering 16,000 gallons of water per minute, or 35.65 second-feet, and all driven by 2 engines of 40 horse-power each. It is claimed that when the water is lowered from 4 to 5 feet by means of the pumps the inflow is so great that the supply appears to be inexhaustible by such means.

The South Dodge canal, owned by the Western Kansas Water Works, Irrigation, and Land Company, is on the south side of the Arkansas, the headworks being about 6 miles west of Dodge. It continues in a general southeasterly course and at a distance of about 3 miles from the river, ending at Mulberry creek, near Ford. The total length when completed will be 30 miles, and the average width about 20 feet. It is proposed to supply water during the summer to this canal by means of 2 centrifugal pumps drawing from a gathering channel similar to that on the north side of the stream.

The canal of the Western Irrigation and Land Company heads on the south side of Arkansas river about 1.5 miles west of Hartland. The main canal is 25 miles in length, and has a width of from 30 to 35 feet near the upper end. The company has also constructed 35 miles of laterals of from 8 to 12 feet in width. The total cost is stated to have been $100,000.

COUNTIES SOUTH OF ARKANSAS RIVER.

Stanton, Grant, Haskell, Morton, Stevens, Seward, Meade, and Clark counties include the area in the southwestern corner of the state south of the Arkansas river. These are for the most part situated within the drainage basin of the Cimarron river, or creek, which cuts across the southeastern corner of Colorado and flows in a northeasterly direction through Morton, Stevens, and Grant counties, then turns nearly at a right angle and continues through Seward and Meade counties, finally crossing the south end of Clark county. This stream and some of its tributaries are the principal source of water supply south of the Arkansas. It is a small, shallow stream, hardly more than a brook, at some parts of its course flowing throughout the summer and at others the water during the hot weather occasionally disappearing through evaporation. (a) A few ditches have been constructed at various points along the banks of the Cimarron, and surveys have been made in order to determine in a general way the feasibility of larger irrigating systems depending for their water supply in part at least upon storage.

Many farmers state that they have tried for at least five years to raise crops, but have failed in nearly every season. The rain is very irregularly distributed, and while some farms may receive it in one year, others do not. All crops and fruit trees do well in the early months of the year, but during the long, dry summer, with its hot winds, they wilt and die unless a rain storm happens to occur at the critical moment. In these 8 counties cereals were raised in 1889 on 57,295 acres. Of this there were in barley and buckwheat 138 acres, in Indian corn 38,414 acres, yielding 8.30 bushels per acre, in oats 5,588 acres, in rye 3,061 acres, and in wheat 10,094 acres, the average yield of wheat being 6.60 bushels per acre.

The largest ditch in use in 1889 was that of the Claremount Land and Irrigation Company, taking water from the Cimarron river, the head of the ditch being near the northeast corner of Beaver county, Oklahoma, 3 miles

---

a When measured on October 23, 1892, by topographers of the United States Geological Survey the discharge was found to be a trifle less than 15 second-feet at a point one-half mile below Arkalon, Kan.

south of the Kansas line and a short distance west of the one hundredth meridian. The total length of the ditch, which ends in Clark county, Kansas, is 8.5 miles, average width 15 feet, and the cost was $6,500. The ditch was built to water the Claremount ranch, there being very little demand for water along the line of the ditch in Oklahoma. The supply is not sufficient for the land under the ditch, especially during the summer. The water is used mainly to irrigate crops sown in the fall, namely, wheat, rye, and barley, it having been found that one irrigation in fall, winter, or spring insures a crop. In Beaver county, Oklahoma, are other ditches taking water from the Cimarron, and also one ditch from Paladora creek, in Grand valley, this stream receiving its water from springs.

ARTESIAN WELLS.

In Kansas there are two small groups of artesian wells in the southwestern corner of the state, in Meade and Hamilton counties, and also several deep wells in various parts of the state, some of which discharge small quantities of water, this being, however, usually saline. In Meade county the wells range from 50 to 210 feet in depth, averaging 153 feet, and with a flow of 49 gallons per minute. Nearly all of them are only 2 inches in diameter, and consist simply of a pipe forced through the unconsolidated clays and sands. The water is reported to be pure and sweet and suitable for all uses. It is employed in irrigation as far as possible, since there are many seasons in which no crops can be successfully raised without the application of water. The first flowing wells were sunk in 1887, and since that time, with the number increased each year, no decrease in the supply has been noted.

In these wells great trouble is frequently experienced on account of the fine sand which flows in and rapidly fills the pipe. This comes with great rapidity at times and in almost inexhaustible quantities. There appears to be little regularity in the stratification of these wells, and it is reported that water is struck at irregular depths, a well on high ground frequently reaching a flow at less depth than one on lower ground.

In Hamilton county, along the Arkansas river, near Coolidge, and also over the line in Colorado, are a few deep wells flowing from 10 to 50 gallons per minute. One of these, 275 feet in depth, 5 inches in diameter, flows at the rate of 20 gallons per minute. The owner has built a reservoir in which to store the water to be used for irrigation. In Morton county, in the extreme southwestern corner of the state, a well was drilled in 1888 to the depth of 700 feet. This is reported to deliver water at the rate of 30 gallons per minute, irrigating a garden containing vegetables, corn, and trees. In other parts of this county water is pumped from shallow wells by means of windmills. At Santa Fe, in Haskell county, a well has been drilled to the depth of over 1,000 feet, but it has been abandoned, although water is reported to have risen to within 50 feet of the surface.

Northerly from this locality, particularly in Logan county, wells are put down to the depth of 300 feet and over in order to obtain water. This usually rises to within 100 feet of the surface. In Trego county, about the center of the western half of the state, a well was sunk to the depth of 650 feet at Gibson, obtaining only a little water at the bottom. Southeasterly from this latter locality, in Pawnee county, on the Arkansas river, at Larned, a well 910 feet deep, 8 inches in diameter, drilled in 1888, at a cost of about $3,500, yields a small amount of water carrying a notable amount of mineral matter. This is reported to flow to the height of 10 feet or more above the surface and to be highly medicinal in character. Near Great Bend, in Barton county, brine has been encountered. At Jetmore, in Hodgeman county, 45 miles westerly from Larned, there is reported to be an unsuccessful well 1,000 feet in depth.

In Reno county, easterly from Pawnee, ordinary water wells are obtained at depths of from 10 to 30 feet, water being brought to the surface by pumps usually driven by windmills. The prevalence of a large amount of water saturating the porous beds beneath the surface has given rise in this part of the state to certain ideas concerning what is called the "sheet water", popularly supposed to be flowing beneath the surface. The structure and character of the unconsolidated layers beneath the surface promote the retention in considerable quantities of the water which falls as rain or snow throughout that part of the state, so that wells dug or pipes driven down to these porous layers receive an ample supply.

In the northeastern part of Kansas several deep wells have been drilled. For example, in Marshall county, at Marysville, a hole was bored for coal to the depth of 1,360 feet, encountering 4 water bearing strata. The casing has been pulled, and the water, saline in character, now flows in a small stream. Westerly from Marshall county, near Jamestown, in Cloud county, there is reported to be a flow of brine. About 50 miles east of Marysville, at Sabetha, in Nemaha county, the railroad company has drilled a well to the depth of 200 feet, the water, it is reported, flowing to the surface.

In the eastern end of the state water is pumped from wells 100 feet or more in depth, and in Miami county are a number of gas wells which have encountered salt water at depths from 200 to 300 feet. South of here, in Bourbon county, near the southeastern corner of the state, are deep wells, some put down for gas, a few of which are reported to discharge a little water. Southeasterly, in Neosho county, it is stated that mineral water is obtained at depths of 100 feet, and in Montgomery county there are probably a few flowing wells on low land.

TEXAS.

PANHANDLE COUNTIES.

In the following discussion of the condition of irrigation in Texas during the census year the counties are taken up in groups according to their geographic position, those in the northern extremity, known as the "Panhandle" of Texas, being mentioned first. Included in this area are the counties of Lipscomb, Hartley, Hutchinson, Hemphill, Oldham, Carson, Donley, Collingsworth, Hall, Floyd, and Motley, where there were in all 22 irrigators and 566 acres upon which crops were raised by the artificial application of water. These counties and the adjoining counties are mainly upon the Staked Plains, where the rainfall is usually sufficient to produce good crops of wheat, oats, barley, potatoes, and grass. The soil throughout this region is very fertile, and with sufficient moisture the yield is always large. Irrigation may be regarded as exceptional, being practiced in only a few localities where water can be readily had.

In Hartley county is a small ditch from Romero spring, and in Hutchinson county another from a creek tributary to the Canadian. South of this, in Carson county, water can be obtained only from wells, this county being on the high divide between the Canadian and Red rivers. Here all kinds of stock, both in summer and winter, find feed on the wild grasses. Water for stock is obtained by means of wells of from 200 to 350 feet in depth, and is raised by windmills, no flowing wells being reported. In a few instances steam power has been introduced for the purpose of pumping water, the supply of which at the depths given is apparently inexhaustible. In Hemphill county, farther down the Canadian river, a little irrigation is practiced. above the town of Canadian by means of water from Clear creek. Farther south, in Childress county, water is obtained from wells of from 40 to 150 feet deep, none of these flowing. South of the Red river, in Hardeman and Wilbarger counties, test wells have been drilled, in the former to the depth of 1,200 feet without success, and in the latter reaching salt water at 320 feet.

TRANSPECOS COUNTIES.

In El Paso and the adjacent counties of Jeff Davis, Reeves, Ward (*a*), Presidio, and Pecos there were 178 irrigated crop areas, having a total of 8,039 acres. These counties lie in the extreme western end of Texas, south of New Mexico and north of the Rio Grande. The surface of the greater part of this region, known as Transpecos Texas, is composed largely of short mountain ranges having a general northwesterly and southeasterly trend and rising abruptly from the plains which surround them. These plains are composed of light materials washed or blown from the mountain masses, and the soil is rich and highly productive whenever irrigated. Various nutritious grasses, the most valuable of which is known as gama grass, are to be found on the plains and hill slopes, furnishing excellent pasturage for cattle. The water supply, however, is so deficient that during a great part of the year there is not enough for cattle to drink, and thus vast areas are rendered useless.

Irrigation is carried on at a number of places along the Rio Grande from El Paso down to Presidio both in Texas and in Mexico. There is a large canal heading at El Paso and carrying water of the Rio Grande to Ysleta, San Elizario, and other small towns down to Fabens. This canal is reported to be 40 miles long and 60 feet wide at the head. Besides this large canal, lately completed, each town has its own acequia, which has been in use for a century or more. The supply of water in the Rio Grande is ample in most years excepting in the months of August and September. In 1889 and 1890 the river ceased flowing about the latter part of July and the bed remained dry until late in the fall, so that the necessities of water-storage were more clearly seen than ever before.

Above the town of El Paso is a suitable locality where, by the construction of a dam at the narrow pass near the town, an enormous amount of water can be held for use during the dry months. This locality has been carefully examined by the United States Geological Survey, and it has been found that by the construction of a dam 60 feet high above the river bed a lake about 14 miles long and 4 miles wide would be created. This lake would contain over 500,000 acre-feet, and of this amount at least 200,000 acre-feet could be made available, an amount sufficient to increase the area under cultivation along the river by at least ten times. The water supply at this point is discussed under the head of Donna Ana county, New Mexico. Among the high mountains there are unquestionably many localities at which flood water can be held in storage reservoirs. In a land utterly devoid of perennial streams, waterworks of this kind have more than usual value, from the fact that they render available vast areas of pasture land, and in some instances render possible the development of the mineral wealth of the country.

In Jeff Davis county, in the vicinity of Fort Davis, a small amount of land is irrigated. Also in Pecos county areas of considerable size in the vicinity of Fort Stockton and to the north of this, toward the Pecos river, are cultivated by means of water from springs. These springs form small creeks, of which the principal are Comanche, Leon, Santa Lucia, and Santa Rosa. A number of ditches take the water from these creeks and bring it out upon the ranches near the southern edge of the Pecos valley.

In Pecos valley some land was cultivated in 1889 by means of water from the Pecos river taken out by the Hardman canal, Pecos River canal, and other ditches. The principal canal, however, is farther up the river, in

---

a Ward county is included in this grouping, although east of the Pecos river.

Reeves county. This is the Pioneer canal, heading about 10 miles northerly from Pecos and carrying water out on the west side of the river in Reeves county. The main ditch is 3.75 miles long and 30 feet wide. Water is to be diverted by means of a brush and stone dam, raising the level about 2.5 feet. At its lower end the main canal branches, the East Valley canal being carried across the Pecos river into Ward county, and the West Valley canal continuing down to and beyond Pecos. When completed there will be about 30 miles of branch or distributing ditches covering the lands between Pecos and Barstow. The cost of the water right is about $10 per acre and the annual assessment $1.50 per acre. The canal is rapidly approaching completion, allowing the cultivation of large areas. Throughout this part of Texas small patches of land are cultivated wherever sufficient water can be found. Corn, wheat, oats, and barley, beans, cotton, and fruit are thus raised. It may be said that planting and harvesting go on continually throughout the year. Often two crops of corn are raised on the same land, or one crop of wheat followed by one of corn; three or four crops of peas are obtained each year, and vegetables are to be had at all seasons if there is sufficient water.

The method of irrigation along the Rio Grande is in general that peculiar to old Mexican settlements. Water is usually applied to the land by flooding within small borders or ridges of earth, these borders being a foot or more in height and about 18 feet apart, dividing the land into squares or rectangles. Water is allowed to flow from one square to another until the surface of the ground is completely saturated. This method requires a large amount of personal attention and care on the part of the irrigator. Attempts have been made in various parts of this region to find water by deep wells.

Along the Texas and Pacific railroad, through western and transpecos Texas, wells have been drilled in nearly every county, but often without success. In Mitchell county, at Colorado city, the well, 1,120 feet in depth, reached salt water, while that to the west, in Howard county, passed through salt water for about 300 feet. In Midland county a hole 350 feet in depth did not reach flowing water, and in Ector county, at Odessa, a well 830 feet in depth was a failure. At Pecos, however, in Reeves county, artesian water has been found, but farther to the west the deep wells have not been successful so far as flowing water is concerned. In El Paso county a well at Torbert 1,100 feet in depth has been abandoned. Another, at Sierra Blanca, 943 feet deep obtains plenty of brackish water, but does not flow. At Finlay a well 1,080 feet deep did not reach good water and was abandoned, and at El Paso no water was reached at 800 feet.

COUNTIES NEAR THE HEAD WATERS OF BRAZOS RIVER.

In the counties lying on or near the head waters of the Brazos river 31 irrigators were reported, having an irrigated crop area of 185 acres. These counties are Taylor, Jones, Shackelford, Young, Baylor, Wichita, Wise, together with the neighboring counties of Hood and Somervell. Nearly all of this land is irrigated by water from wells, either flowing or raised by windmills. At Abilene, Taylor county, a small acreage is irrigated by a ditch from Cedar creek and also by windmills. Nearly all crops can be raised in ordinary seasons without irrigation.

In several instances farmers have constructed reservoirs to hold rain and flood waters. In Young county, for example, a reservoir is being built by a farmer, the dam for which is 700 feet long, 140 feet wide at base, and 40 feet at top. Water is to be brought to this in part by a ditch running around the hillside to enlarge the drainage area tributary to the reservoir. When full about 5 acres will be covered to a depth of from 8 to 10 feet. This water will be distributed by means of pipes and open ditches. In Somervell county nearly all the irrigation is being done by artesian wells, although in the valleys large areas could be covered by ditches taken from perennial streams. In the vicinity of Glenrose there are at least 60 artesian wells, from 200 to 400 feet in depth. The cost ranges from $150 to $500 each. The water has been successfully used to irrigate cotton, Indian corn, ribbon cane, and garden vegetables. It is asserted that there are 200 of these wells in the Paluxy valley.

TOM GREEN AND ADJOINING COUNTIES.

In Tom Green and other counties on the head waters of the Colorado river and extending to and including Lampasas county there were 159 irrigated crop areas, having a total of 5,531 acres. These counties, named in order are, Martin, Midland, Irion, Tom Green, Concho, Menard, McCulloch, Coleman, Brown, San Saba, and Lampasas. Water for irrigation is taken principally from the small tributaries near their heads, comparatively little being diverted from the main streams at points where they have attained a size sufficiently great to be called rivers. The more southerly of these counties, especially San Saba and Lampasas, are noted for the large springs which form the main source of supply for the creeks. A few of these springs discharge as much as 5 second-feet and are so situated that the water can be used for running machinery, such as flouring mills. Many of these, however, have not been utilized in any way and the water runs to waste.

The Concho river and many of the creeks supplying it rise in the edge of the Staked Plains and flow in a general southeasterly course nearly parallel with the Red fork of Colorado river, with which it finally unites. All of these streams can be utilized for irrigation, since it would be a matter of comparatively small expense to divert for irrigation, the discharge being probably more constant than that of the other rivers and the lands to be irrigated at a relatively low altitude.

In Menard county the greater part of the area irrigated is covered by the ditch of the Vaughan Agricultural and Mechanical Company, taking water from the south side of the San Saba river. This stream is fed mainly by springs and flows throughout the year. The head of the ditch is 4 miles west of Menardville. The length is about 9 miles, average width 8 feet, and the cost was $20,000. The annual charge for water is $2 per miner's inch, 100 miner's inches being the quantity discharged through a box 10 inches square under a head of 2 inches. Under this canal small grain is irrigated at intervals of from 12 to 15 days, corn at from 15 to 20 days, and cotton at from 18 to 25 days.

The value of irrigation in this locality may be judged from the fact that land worth $1.50 per acre before being brought under irrigation is after the introduction of this method of agriculture valued at $50 an acre at least. By thorough watering it is reported that from 1 to 2 bales of cotton per acre are raised, while on the same land without water less than one-fourth bale can be raised. The annual charge to the irrigators is $2 per miner's inch a year, an inch being supposed to water an acre. Water is applied to the cotton by running it in furrows, and to small grain by flooding.

In Irion county, in the vicinity of Sherwood, are a number of small ditches, of which the principal are the Lackey and McDonald ditches, taking water from Spring creek, and Stetson ditch, taking water from Dove creek, both of which creeks are tributaries of Concho river, one of the branches of the Colorado river. The water, as in the case of the other streams, comes mainly from springs, and there is an amount ample for all present needs. Alfalfa, grass, wheat, oats, and other grains are irrigated by flooding, while the corn, potatoes, and gardens are kept wet by means of furrows. It is reported that cotton is becoming a favorite crop for irrigated land, 1.5 bales or more to the acre being raised. At localities away from the streams water is obtained at depths of from 50 to 100 feet and is raised to the surface by means of windmills. The Sherwood irrigating ditch takes water from Spring creek, 2 miles west of Sherwood, and carries it out on the south side of the creek for a total distance of about 3.5 miles. The width is 6 feet, and the cost when built, in 1884, was $1,000. Water is diverted from the river by a dam of rock and planks. In 1889 about 300 acres were irrigated, this area being largely in oats and sweet potatoes, together with gardens. In 1890 cotton was tried for the first time, three-fourths to one bale per acre being raised.

East of Irion county, and farther down the stream, in Tom Green county, are a few small ditches irrigating land above San Angelo, the principal crops being corn, cotton, oats, beans, pease, and minor vegetables. Farther up the Concho river, in Martin and Midland counties, a small amount of irrigation is carried on by means of water pumped from wells of a depth of 10 to 100 feet. On the Staked Plains wells of this latter depth seldom fail to find ample water, and the wind movement is sufficient to keep mills in active operation. The water is carefully controlled and allowed to flow into small basins around each fruit tree, or run in furrows to vegetables, so that a comparatively small amount is sufficient for a large area. At Marienfield projects for greatly increasing the fruit area have been started, and there is probability that the acreage will increase rapidly.

TRAVIS AND NEIGHBORING COUNTIES.

In Travis and the adjacent counties of Williamson, Burnet, Coryell, Bell, Falls, and Milam there were 19 irrigators and a total irrigated crop area of 364 acres. In these counties irrigation is exceptional, since crops are raised each year without the artificial application of water. A few small farms, however, scattered here and there are irrigated by means of little ditches from springs, by flowing wells, or by water pumped by windmills. The yield per acre is greatly increased by this means, and vegetables are raised at nearly all seasons.

In Travis county, about 15 miles northwest of Austin, a small ditch is taken out of Cypress creek, which receives its water mainly from springs, and market gardens are irrigated. In Coryell county, on Leon river, 5 miles southeast of Gatesville, the Sheridan ditch takes water from Fort Gates creek. This stream generally furnishes ample water, but becomes dry perhaps once in 12 or 15 years. Corn, cotton, and sweet potatoes are irrigated, as well as various garden vegetables. For sweet potatoes and cabbage water is used from the middle of April to the middle of September at intervals of about 15 days, and for cotton from the 15th of June to the 1st of October at the same intervals.

BEXAR AND NEIGHBORING COUNTIES.

In Bexar and other counties lying southwest of Colorado river and south of San Saba river, one of its branches, there were 139 irrigated areas, having a total of 1,009 acres. These counties in order from north to south are Mason, Llano, Kimble, Gillespie, Blanco, Kerr, Kendall, Hays, Bandera, and Bexar. As in the case of the other areas described, a large part of the irrigation is carried on by water from springs. At San Antonio, in Bexar county, however, water is obtained directly from San Antonio river by means of two ditches, one on each side of the stream. These ditches were constructed by the early Mexican settlers, and have been controlled largely according to customs instituted by the first inhabitants. There are two commissioners, whose duty it is to superintend the ditches on the east and west side of the river, to keep them clean and in repair, and to see that all parties entitled to the water receive their proper share. Crops are raised in the vicinity without irrigation, but this method of agriculture possesses the advantage of enabling market gardeners to raise vegetables throughout the year. There are also in the vicinity of San Antonio a number of artesian wells.

In Hays county some water is taken from Cypress fork of Blanco river by two or more small ditches, one of which is used mainly for supplying power for a mill. In this county there is reported to be a flowing well of a depth of 131 feet 5 inches in diameter, flowing at the rate of less than a gallon a minute. In all of these counties the small irrigating ditches are occasionally not used for weeks at a time, since the ground often receives sufficient moisture from rains. Some of the farmers speak unfavorably of irrigation, saying it robs the soil of its richness, and that a heavy application of fertilizers is necessary. This perhaps is because the spring water used is generally very clear, and if employed in excess it washes away valuable mineral salts.

In Kimble county attempts have been made to divert water from the South Llano river at a point 4 miles above Junction by means of a dam 7 feet high. This, however, has been injured by spring freshets, so that irrigation on a considerable scale has not been possible. There is a large amount of fine, rich valley land, and usually ample water in Little Llano river. Corn, oats, wheat, sorghum, cane, and potatoes are now raised without irrigation. Where water can be had four crops of alfalfa are obtained.

VALVERDE AND NEIGHBORING COUNTIES.

In Valverde and the neighboring counties of Edwards, Kinney, Uvalde, Medina, Maverick, Zavalla, Dimmit, and Lasalle were 75 irrigated crop areas, having a total of 2,547 acres. These counties lie along and northeast of the Rio Grande, extending from the mouth of the Pecos to the head waters of tributaries of Nueces river, which flows in a general southwesterly direction, parallel to the Rio Grande, into the Gulf of Mexico. Over a great part of these counties crops can be raised without irrigation, but with it the yield is larger, and there is greater assurance of success.

All of the irrigation is done by means of water from springs or from small creeks formed by these. The water is usually clear, since it comes from limestone strata, and does not carry in suspension the fine sediment so valuable for fertilizing purposes. In this it differs from water from the Rio Grande, which is remarkably rich in silt. Great care, therefore, must be used in applying this water in order that it may not wash away valuable salts already contained in the soil. The principal crops are corn, cotton, sugar cane, sorghum, wheat, oats, and hay. Whenever water is abundant these are irrigated at short intervals throughout the year unless there happens to be an unusual amount of rain.

At the town of Del Rio, in Valverde county, lands are watered by means of ditches from San Felipe creek. Water is turned into the laterals of shareholders for from 2 to 5 hours per share at intervals of 15 days. It is applied to the land usually in the old Mexican method, and since many of the laborers are unreliable or unskilled, the results are not always satisfactory, the lands sometimes being washed or injured by careless application. Irrigated land, however, is quoted as selling at $100 per acre. In general 2 crops of corn are planted, the first in February or March, and the second in June. It is stated that the June corn, coming probably from Mexico, does better than the earlier corn. Three or sometimes 4 crops of sorghum are raised, mainly for feed. At this town there is a well sunk to a depth of about 430 feet. Water rises within 45 feet of the top, but it is reported to be heavily charged with mineral matter.

In Zavalla county water is taken from the west side of the Leona river by the ditch of the Comanche Irrigation Company. This stream is a tributary of Frio river, which flows into the Nueces. It is fed by springs, is rarely dry, but is subject to occasional floods from local rains. The ditch is 3 miles long, about 8 feet wide, and carries approximately 6 second-feet. Water is diverted by a permanent dam of wood, brush, and stone. Water is distributed to those entitled to it, each person using the full stream for as many hours as he has acres in cultivation. The first cost of water right was about $12 per acre, and the annual assessment 50 cents an acre. Crops in this county are raised without irrigation, but the farmers state that they can not be sure of more than 2 crops in 3 years.

In Frio county, east of Zavella, are several flowing wells. On one farm about 20 miles southeast of the center of this county, on San Miguel creek, are three, 160 feet, 266 feet, and 391 feet in depth, respectively, flowing at the rate of 5 gallons, 8.5 gallons, and 6.5 gallons a minute. The third well is on higher ground, and though much deeper discharges less water than the second. In no case does the water rise more than 7 or 8 feet above the surface of the ground. The cost of such wells is usually $1 a foot for the first hundred feet, $1.50 a foot for the second hundred feet, and so on, 50 cents per foot being added for each increase of 100 feet. These wells are usually cased with pipe from 3 to 6 inches in diameter, costing from 25 to 75 cents per foot. Still farther to the east, in Atascosa county, is a well 315 feet deep, in which the water rises to the top.

In the counties of southern Texas, south of the Colorado river, flowing wells are found irregularly distributed from about the vicinity of San Antonio down to the coast. The wells in Hays, Bandera, and Gonzales counties are small and shallow, yielding only enough water for cattle. In Bexar county the wells are mainly at San

Antonio. These are upward of 800 feet in depth. In Medina county a well 1,000 feet in depth did not reach fresh water. In Uvalde county, west of Medina, the water obtained from flowing wells is reported to be impregnated with mineral matter, but, on the contrary, south of this locality, at Carrizo Springs, in Dimmit county, the water from artesian wells is sufficiently pure to be used for irrigation. In Webb county, south of Dimmit, at Laredo, on the Rio Grande, there have been repeated failures in the attempt to secure flowing water. To the eastward, near the coast, fresh water has been obtained in Victoria county from wells 825 to 946 feet in depth. This water will rise to a height of 50 feet above the surface. At Corpus Christi, in Nueces county, a well 1,700 feet in depth contains water highly charged with mineral matter.

ARTESIAN WELLS.

In the preceding description a number of flowing wells have been mentioned, mainly in connection with their use in irrigation. In the following paragraphs, however, mention is made of the artesian wells which were enumerated without special regard to the way in which their waters were utilized. These wells are as a whole found mainly near the center of the state, scattered over a broad belt extending in a general north and south direction between the ninety-sixth and ninety-ninth meridians, the greater number being in the vicinity of the cities of Dallas, Fort Worth, Waco, and towns farther to the south. The position of these wells is governed by the peculiar geologic structure of the state, the largest number of wells being located in such position that they reach a thick sandstone at the base of the cretaceous, known as the Trinity sands. This sandstone, as described by R. T. Hill, comes to the surface in an irregular line extending from Cooke county southwesterly and southerly through Montague, Wise, Parker, Erath, Comanche, Mills, Lampasas, Burnet, and Blanco counties. From this line of outcrop the sandstone dips easterly or southeasterly, at a gentle angle, toward the Gulf, the dip being slightly greater than the fall of the surface, so that the bed is found at a greater and greater depth as borings are made to the eastward.

The principal flowing wells of the state are found within the belt of country about 80 miles in width lying to the east of this outcrop, but this area by no means includes all of them. There are other sandstones lying above the Trinity sands which also slope toward the Gulf faster than the land descends, and at localities in southeastern Texas, where the Trinity sands are buried too deep to be reached by the drill, these overlying porous layers are frequently pierced, yielding artesian flows. The wells, however, receiving water from these sandstones do not as a rule yield as large a quantity, and there is less certainty of success in the deep borings for water.

West of the line where the Trinity sands come to the surface, as above described, is a group of rocks which belong mainly to the coal measures and dip toward the west and northwest, having in general a basin-like structure. Flowing wells have been obtained near the edge of this basin, but the water is generally saline in character or so heavily charged with mineral matter as to be unfit for most purposes.

In the following descriptions the counties will be taken up in general order from north to south. The most northerly well is probably in Grayson county, 16 miles northwest of Sherman, and was bored in the search for coal. This is 480 feet in depth, and is reported to have passed through 3 water-bearing strata at 140, 160, and 180 feet from the surface, respectively. A pure water, pleasant to the taste, now flows from the lowest water bearing sandstone. The well is situated in heavily timbered creek bottom land, and the water has been of little use. At Paris, in Lamar county, 75 miles east of this point, a well has been drilled to the depth of nearly 450 feet, but without obtaining flowing water. In Denton county, southwest of Grayson county, the wells on the low ground, averaging 350 feet in depth, discharge small quantities of water, while those on the higher land are pumped for the purpose of furnishing water for cattle.

In Jack county, about 60 miles west and therefore outside of the area underlaid by the Trinity sands, there are reported to be a number of flowing wells of a depth of about 100 feet. These wells and others now pumped by windmills were drilled for the purpose of obtaining water for stock. Southwesterly from this locality, in Palo Pinto, Stephens, and Eastland counties, which, as in the case of Jack county, are within carboniferous areas, a number of wells have been drilled in order to prospect for coal. At Strawn a well 546 feet deep, and costing $700, discharges mineral water which comes from a depth of 321 feet beneath the surface. At Graham, in Young county, a well 300 feet deep reached salt water only. In Stephens county wells averaging 130 feet in depth discharge from 3 to 10 gallons per minute of water suitable for cattle. In one instance irrigation has been successfully tried on a small scale, but the amount of water available is too small to be economically handled. At Breckenridge, in this county, a well was drilled to the depth of 1,400 feet, but without success, and in Eastland county, at the town of the same name, about 25 miles south of Breckenridge, a well 1,300 feet deep is reported to be a failure. Another well at Cisco, about 7 miles west, was drilled to the depth of 1,680 feet, passing through strata bearing salt water.

In Parker county, east of Palo Pinto, there are several shallow flowing wells discharging a small amount of water. At Weatherford a hole was drilled to the depth of about 500 feet, the principal amount of water, however, being found near the surface. In Tarrant county, still farther to the east, are a larger number of deeper flowing wells, delivering on an average about 10 gallons per minute of good, soft water. The average depth of these wells is 207 feet. At Fort Worth, however, 2 wells have been drilled to a greater depth, one being over 750 feet deep and discharging a small stream, while the other, 950 feet deep, is reported to flow at the rate of 140 gallons per minute. In Dallas county there are also a large number of flowing wells similar to those near Fort Worth, the water being used, as in the case of the other counties, mainly for cattle, irrigation not being necessary. Many of these wells are not tubed or cased except for a short distance near the top, and doubtless a great deal of water is lost in the porous strata.

In the counties of the next tier to the south, namely, Hood, Somervell, Johnson, and Ellis, wells are mainly from 80 to 300 feet in depth, and do not differ essentially from those previously mentioned. In one instance, at least, the water has been used for irrigating cotton, corn, cane, and vegetables in an experimental way with marked success. It is stated that in Hood county a large number of the wells have from one cause or another ceased flowing. At Cleburne, in Johnson county, 4 wells, each of about 360 feet in depth, did not obtain flowing water. In Ellis county instances are given of the irrigation of a few trees, but otherwise the water was not used except for cattle and household use. At Hillsboro, in Hill county, 25 miles southeasterly from Cleburne, a well was drilled to the depth of 500 feet without success. West of this, in Bosque county, however, are many flowing wells from 400 to 600 feet in depth. The water from these is generally soft and palatable, although there are statements to the effect that it is occasionally impregnated with salt, and that, while stock will drink it, it is not suitable for irrigation. Several of the wells have stopped flowing, owing possibly to defects in casing.

West of Bosque county, at Lanham, wells were drilled nearly 500 feet in depth without success, and at Brownwood, in Brown county, still farther to the west and outside the area underlaid by Trinity sands, a well 1,100 feet in depth obtained only salt water. In Coleman and McCulloch counties, however, wells drilled in the carboniferous rocks are stated to yield water nearly if not quite fresh. The strata in these counties dip gradually to the west or northwest, and the water evidently comes from rainfall in the counties toward the east and south.

South of Bosque county, in Coryell, McLennan, and Bell counties, are groups of wells yielding water in general suitable for stock. In one or two cases it is reported that irrigation has been tried, but that the water was found to be too heavily charged with mineral matter. At Belton a well 1,000 feet deep is stated to yield 160 gallons a minute. At Waco are a number of deep wells, put down by water companies and having a depth of upward of 1,800 feet. These are stated to flow at the rate of from 300 to 700 gallons per minute, or from 0.67 to 1.56 second-feet, and the water is excellent for city purposes. In Burnet county, west of Bell, the wells are shallow, less than 100 feet in depth, and discharge small quantities of water, used in cooking and drinking.

In the counties of Robertson, Brazos, and Burleson, along the valley of the Brazos river, the wells are mainly from 300 to 500 feet in depth, and in the aggregate they yield a large amount of water. None of it has been employed for irrigation, except possibly in an experimental way, for there is usually a rainfall ample for the crops of that country, which consist mainly of cotton and corn. In Robertson county especially a considerable proportion of the wells do not flow, but are pumped in order to obtain water for cattle. At Bremond a well 1,500 feet in depth does not discharge, although the water rises toward the surface.

In Washington county, at Brenham, a well was drilled to the depth of 600 feet, but without success. From this point southerly and southeasterly to the coast there are comparatively few flowing wells, although many attempts are being made to obtain them. At Houston, however, are a number of great value to that city. In Galveston county borings have been made through the coast clays, and artesian water has been found in several localities at depths of from 400 to 700 feet or more. A well at Hitchcock delivers about 100 gallons per minute, and another at Highland flows at the rate of 8 gallons a minute. Some of the water from these wells is used on vegetables and strawberries, but these are about the only attempts at irrigation.

o

APPENDIX.

DATA CONCERNING WATER SUPPLY.

GENERAL STATEMENT.

This appendix is intended to bring up to date of publication the facts obtained concerning the water supply available for irrigation. It has been prepared in accordance with a resolution introduced on January 21, 1896, by Hon. Francis E. Warren, chairman of the Senate Committee on Irrigation. The report to which this is an appendix was prepared during the years 1890, 1891, and 1892, a large portion of it being printed as separate bulletins of the Census Office. The material for its preparation was obtained primarily through the census enumeration of 1890, and through schedules mailed during subsequent years to irrigators and owners of irrigation canals. The facts thus acquired were supplemented by personal information and by the field work of the irrigation survey, a branch of the United States Geological Survey. The data concerning water supply and the condition of the country were obtained mainly through the latter source. The figures as to river measurements and fluctuations of streams in this report were complete to the end of 1892. In the final editing of the report the attempt was made to make the description refer back as much as possible to conditions in 1890, and dates scattered through the description referring to later years were either struck out or the material was put in the form of footnotes. It is now desired to bring up to the date of publication of the second edition (April, 1896) the facts which have been collected since 1892, in order to round out the report and make it more useful.

The progress of irrigation and the changes since the times described in the body of this report have not been notably great. Throughout the country as a whole there has been steady progress, the number of irrigators has increased, especially in the debatable ground of the subhumid region, and the acreage has also expanded year by year. But this growth has taken place principally under the irrigating systems already described, few other notable works having been constructed. The years 1889, 1890, and 1891 are remarkable in the history of irrigation from the large share of public attention attracted, the enormous investments of capital in irrigation works, and the sudden expansion of this method of agriculture. Many large systems of irrigation works were constructed in whole or part and thousands of acres of land were brought under water. The construction of canals, however, did not insure the immediate cultivation of the land, and while many projects have been well conducted from an engineering point of view, yet the great majority have not been financially successful. This is due primarily to the difficulty of securing settlement of the lands under the canals by a sufficiently large body of industrious and contented farmers. One of the greatest curses of the country is the large number of restless men eager to speculate, constantly on the lookout for opportunities of making money without labor, always ready to take up land under a new enterprise, and to make feeble attempts at farming in the hope of selling out to someone who will really cultivate the soil. These men are rarely successful with their crops, frequently default in their payments, and their presence serves merely to embarrass and retard settlement. The true farmer—hard-working, intelligent, and progressive—is a very difficult man to transplant to new localities. To secure a sufficient number of men of his class and to settle them on irrigated lands is perhaps a more serious undertaking than the raising of the necessary capital and the construction of the work itself.

During the years when settlers are slowly coming in and the land is being brought under cultivation, the interest, charges, and the cost of maintenance are as great or greater than at any other period, and the management of many a good system of water supply becomes embarrassed for lack of funds. The financial depression of late years, following immediately after the construction or partial completion of many of the great irrigation systems, has multiplied the difficulties of maintenance and administration, so that comparatively few irrigation enterprises have been in a healthy state of growth and expansion. Extravagant assertions are still made as to the area now irrigated (1896), and several states claim to have each alone as much land under irrigation as that given by the census enumeration and shown in the table on page 1. It is improbable that a careful farm to farm census would discover more than a small percentage of the area claimed, or that the total extent actually irrigated and cropped in the whole arid region is more than twice the amount shown in 1890. This, however, is no indication of the possibilities of the country, nor are the discouragements incident to overconfidence and to the succeeding years of depression to be taken as indexes of the future. The lessons of the past show that where projects have been well considered, where all of the advantages and disadvantages have been carefully weighed, and the true conditions known, results of great importance and value have been achieved. It is not possible, however, to legitimately draw out great profits from irrigation systems hastily constructed and crudely managed.

One of the lessons of the past has been that an irrigation canal can not be in itself of immediate profit to its owners. The attempt to maintain a canal and make a profit out of sales of water rights and of annual rental has, with few exceptions, been a failure. The first cost of each canal should be ultimately paid out of the increased value of the land, and not by the sale of water rights to persons who have already purchased the land and paid to speculators the value of the land plus the increase due to the presence of the canal.

THE IMPORTANCE OF FACTS CONCERNING WATER SUPPLY.

One of the most important elements of success in the development of irrigation, and one which is most commonly overlooked, is exact knowledge concerning the amount of water available for each project. From the fact that there has been very little information available in the past, and because of the great haste to invest in speculative enterprises, there has been a tendency to ignore all information of this character. The average investor and constructor has proceeded as rapidly as possible to build his ditch, trusting that somehow or other he could obtain and hold enough water to fill it, or that he could dispose of his interest in the property before complications arose. As a result there are almost innumerable controversies concerning water and water rights in every state and every county. If the facts could be known it appears highly probable that it would be shown that many of the farmers pay out a sum each year in lawyers' fees, court expenses, or for various forms for protection, larger than they expend for the maintenance of the distributing system. Much of this waste of time and money would be obviated were the facts as to the amount of water and its fluctuation made known to the public and properly recorded.

Not only is the knowledge of water resources of importance in settling local questions, but it has a wider and more general application in considerations of the reclamation of the unoccupied lands, both public and private, and the possible spreading to new regions of agriculture and civilization. As shown by the following table the United States still owns one-third of its total area, exclusive of Alaska. Within this third are some of the most productive soils of the world. The sole lacking element is water, and where this can be supplied the lands have great value.

TOTAL LAND SURFACE, AREA DISPOSED OF, RESERVED, AND VACANT IN WESTERN PUBLIC LAND STATES.

STATES. (a)	Land surface. (b) (Square miles.)	AREA DISPOSED OF.			AREA RESERVED.			AREA VACANT.		
		Square miles.	Acres.	Per cent.	Square miles.	Acres.	Per cent.	Square miles.	Acres.	Per cent.
Total	1,550,965	435,316	278,602,289	28.07	162,134	103,765,511	10.45	953,515	610,249,600	61.48
Arizona	112,920	6,634	4,245,809	5.87	20,378	13,042,266	18.05	85,908	54,981,120	76.08
California	155,980	56,445	36,124,612	36.19	9,320	5,965,067	5.98	90,215	57,737,600	57.83
Colorado	103,645	30,104	19,266,473	29.04	6,607	4,228,480	6.38	66,934	42,837,760	64.58
Idaho	84,290	5,708	3,653,222	6.77	3,483	2,228,847	4.13	75,099	48,063,360	89.10
Indian territory	31,000	....	....	....	31,000	19,840,000	100.00	....	....	....
Kansas	81,700	80,410	51,462,207	98.42	150	96,445	.18	1,140	729,600	1.40
Montana	145,310	16,196	10,365,367	11.14	15,057	9,636,224	10.37	114,057	72,996,480	78.49
Nebraska	76,840	59,358	37,989,270	77.25	296	189,428	.39	17,186	10,999,040	22.36
Nevada	109,740	3,906	2,500,000	3.55	1,263	808,215	1.15	104,571	66,925,440	95.30
New Mexico	122,460	29,688	19,000,000	24.24	7,470	4,780,617	6.10	85,302	54,593,280	69.66
North Dakota	70,195	30,169	19,307,913	42.98	6,936	4,438,732	9.88	33,090	21,177,600	47.14
Oklahoma	38,830	12,302	7,873,118	31.68	11,315	7,241,378	29.14	15,213	9,736,320	39.18
Oregon	94,560	28,581	18,291,809	30.23	10,092	6,458,880	10.67	55,887	35,767,680	59.10
South Dakota	76,850	35,695	22,844,814	46.45	15,951	10,208,627	20.76	25,204	16,130,560	32.79
Utah	82,190	7,812	5,000,000	9.51	7,070	4,524,628	8.60	67,308	43,077,120	81.89
Washington	66,880	26,257	16,804,767	39.26	7,866	5,034,069	11.76	32,757	20,964,480	48.98
Wyoming	97,575	6,051	3,872,906	6.20	7,880	5,043,418	8.08	83,644	53,532,160	85.72

a Including 4 territories.

b Area as given by Henry Gannett in Bulletin No. 23 of Eleventh Census.

Water is the foundation of all values for the public lands and for enormous tracts now in private ownership. Without it the land is practically useless. This fact has been dwelt upon more fully in a paper upon the Public Lands and their Water Supply, published as part of the Sixteenth Annual Report of the United States Geological Survey. This report illustrates by maps and diagrams the extent of the public lands, their character, and dependence upon irrigation for future development.

The systematic investigation of the water resources of the country was begun by the irrigation survey in 1888. After the discontinuance of appropriations the work of the Division of Hydrography was continued in a small way. In the fall of 1894 this division was reorganized under the terms of the appropriation act of August 18, 1894 (Statutes at Large, volume XXVIII, page 398). This division has been actively engaged in field work in all parts of the arid and semiarid region measuring the streams and determining the water supply and studying the available sources from artesian and other wells. The information gathered has been published in part in progress reports printed as bulletins, and in part as papers accompanying the annual reports of the United States Geological Survey. The statements given in the following pages are to a certain extent compilations of facts given at greater length in other publications or scattered through various documents.* For convenience of reference they are arranged under the heading of the various states and territories, these being given in the order adopted in the main report.

The methods employed have been described in the reports just mentioned. In general, the streams are measured at various times and localities by the use of mechanical devices known as current meters. By means of these the velocity in different parts of the stream is ascertained, and the total discharge computed by multiplying the area of the cross section of the stream by the speed at which it flows. At certain points, or river stations, series of observations have been maintained giving the fluctuation in height of the water, and by means of these and by the measurements made at various heights computations have been completed giving the probable discharge for each day of the month or year, thus affording means of knowing the greatest and least flow, the total amount discharged for any period, and the value of the stream for irrigation or for water power. Such figures also bring out the availability of the river or creek for storage, and the degree of reliance which can be placed upon reservoirs constructed for the purpose of supplementing the low water flow. They also show what may be expected in the way of floods, and warn the engineer as to the forces he may expect to tear down his structures. It is, of course, not possible to measure every stream, but the information obtained concerning one stream is of great value if intelligently applied in estimates of other rivers or creeks under the same topographic or climatic influences.

---

*LIST OF REPORTS ON STREAM MEASUREMENTS.

Report of Progress of the Division of Hydrography for the calendar year 1895, by Frederick Haynes Newell, hydrographer in charge; issued as Bulletin No. 140 of the United States Geological Survey.

Report of Progress of the Division of Hydrography for the calendar years 1893 and 1894, by Frederick Haynes Newell, topographer in charge; published as Bulletin No. 131 of the United States Geological Survey.

The Public Lands and Their Water Supply; issued as an extract from Part I of the Sixteenth Annual Report of the United States Geological Survey.

Results of Stream Measurements; published as a portion of Part II of the Fourteenth Annual Report of the United States Geological Survey.

Water Supply for Irrigation; published as a portion of Part III of the Thirteenth Annual Report of the United States Geological Survey.

Hydrography of the Arid Region; published as a portion of Part II of the Twelfth Annual Report of the United States Geological Survey.

ARIZONA.

In this territory comparatively little work has been done in the investigation of the water resources, owing to the large expense involved for transportation and the extreme difficulty of securing regular observations of river height. There are few, if any, inhabitants along the rivers at points above the heads of the most important canals, and, so far as seen, most of these persons are not sufficiently well informed to record the observations of river height and to forward them to the engineer in charge. To obtain definite information of value it will be necessary to spend a larger amount proportionally than in almost any other part of the arid west. This is especially to be regretted, as the developments in the Salt River valley in the vicinity of Phenix have been very great and the population dependent upon the water supply has increased rapidly. On page 27 are given computations of the discharge at Arizona dam above Phenix, these being obtained from Mr. Samuel A. Davidson, at that time engineer of the Arizona canal. The results of later computations are shown on the following page. In the fall of 1895 work was begun on the Gila river at the Buttes above Florence, for the purpose primarily of ascertaining the water supply for the Gila River Indian reservation. The investigations were made by Mr. Arthur P. Davis, assisted by Mr. Cyrus C. Babb. The results of the river work are given in condensed form with others below.

MEASUREMENTS OF ARIZONA RIVERS.

GILA RIVER AT BUTTES, ARIZ. (See page 30.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
December 28	2.35	3.70	585
December 31	2.23	3.55	519
1896.			
January 5	2.10	2.93	397
January 12	2.03	3.30	436
January 19	1.92	3.00	398
January 25	1.79	2.20	270
January 26	1.78	2.83	268
February 8	1.73	2.70	317
February 9	1.70	2.20	240
February 12	1.73	2.40	251
February 18	1.74	2.46	260
February 22	1.75	2.30	253
March 4	1.80	2.00	196
March 8	1.79	2.26	218
March 10	1.80	2.00	214
March 13	1.88	2.38	258
March 21	1.81	1.94	187
March 26	1.71	1.79	137
March 28	1.70	1.95	149
COLORADO RIVER AT YUMA, ARIZ. (See page 29.)			
1876.			
March 20			[a]7,659
1895.			
January 17	19.66	3.80	9,737
April 18	20.25	5.23	21,095
July 10	21.20	5.46	45,533

[a] See Twelfth Annual Report United States Geological Survey, Part 2, page 292.

ESTIMATED MONTHLY DISCHARGE OF ARIZONA RIVERS IN SECOND-FEET.

[Data from Hudson Reservoir and Canal Company].

VERDE RIVER AT MOUTH. (See page 26.)

(Drainage area, 6,000 square miles.)

MONTH.	Maximum.	Minimum.	Mean.
1895.			
January	23,000	527	4,037
February	5,800	583	1,688
March	8,400	1,887	3,720
April	2,800	280	750
May	429	127	258
June	180	129	153
July	275	116	145
August	1,426	165	359
September	348	141	176
October	3,912	197	475
November	1,800	241	463
December	881	345	391
SALT RIVER ABOVE MOUTH OF VERDE. (Drainage area, 6,260 square miles.)			
1895.			
January	49,706	791	5,733
February	3,892	914	1,445
March	3,340	1,319	1,829
April	2,939	1,044	1,860
May	990	505	708
June	500	203	325
July	896	145	204
August	1,516	226	584
September	684	201	329
October	13,205	390	1,624
November	9,620	380	1,376
December	2,055	513	888
SALT RIVER AT ARIZONA DAM. (See page 27.) (Drainage area, 12,260 square miles.)			
1895.			
January	82,000	1,318	10,093
February	9,766	1,497	3,133
March	6,833	3,219	5,532
April	5,769	1,324	2,594
May	1,270	665	966
June	679	340	479
July	1,086	262	350
August	2,223	453	947
September	1,159	354	503
October	17,015	583	2,095
November	10,820	615	1,839
December	2,275	873	1,279

CALIFORNIA.

The investigations made by the state engineer of California and by the United States Geological Survey have been described on pages 37 and following, and the results given up to the end of 1892. At a later time work in that state was resumed, a number of river stations being established by Mr. Arthur P. Davis and put under the charge of Mr. J. B. Lippincott. The greater part of the field work has been in the San Joaquin valley, there being a small amount in the Sacramento valley and in southern California. On the Sacramento river a series of measurements have been made at Red Bluff and at Jellys Ferry, about 10 miles above this point, where the conditions are more favorable for obtaining accurate results.

In San Joaquin valley a number of streams have been measured from the upper or southern end of the valley in the vicinity of Tehachapi creek northerly along the western foothills of the Sierra Nevadas. Estimates of the discharge of Tejon House creek have been obtained through Mr. R. M. Pogson. Westerly from this is Pastoria creek, a number of measurements of which have been made by Mr. J. B. Lippincott. The discharge of Kern river has been measured by the engineers of the Kern County Land Company, the point of measurement being above the head of the canals irrigating the lands in the vicinity of Bakersfield.

A long series of observations of fluctuations of height of the San Joaquin river have been made at the upper railroad crossing of the Southern Pacific Company near Herndon. This point is favorable for discharge measurements, and several of these have been made giving data for the computation of the daily discharge during 1895. Kings river has been measured at Kingsburg, and also at a suspension bridge about 30 miles higher upstream, this being above the head of ~~most~~ of the canals and a more favorable point for measurement. Tuolumne river has been measured at Modesto, and also higher upstream near the Lagrange dam, built across that river for the purpose of diverting the water into the canals of the Turlock and Modesto districts. Stanislaus river has been measured in the vicinity of Oakdale, and Mokelumne river near Lodi.

In southern California measurements have been made of a number of the rivers which rise in the Sierra Madre, or San Bernardino range northerly from the cities of Los Angeles and San Bernardino. San Gabriel river is one of these, which, rising in a very steep catchment area, flows out through narrow canyons to the low valley adjacent to the seacoast. The water in this canyon is diverted, the greater part of it being used for irrigation. During 1894 Mr. H. F. Parkinson made computations of the daily discharge, the point of measurement being about 2 miles north of the town of Azusa. This was during a dry year and all of the water was used for irrigation. In 1895 similar investigations were continued and a river station established at the point of diversion.

Santa Ana river, the most important source of water supply for San Bernardino valley, rises to the east of San Gabriel. Within its drainage basin is contained the large storage reservoir of the Bear Valley Company, and a number of important irrigation systems depend upon it for supply (see page 71). Estimates of discharge have been made by the engineers of the Bear Valley Company. The results of the computations of the average discharge, by months, are given in the following table:

ESTIMATED MONTHLY DISCHARGE OF SANTA ANA RIVER IN SECOND-FEET.

MONTH.	1881	1882	1883	1884 (a)	1885
January	24+	24+	24+	700.0	48.0
February	24+	24+	24+	1,000.0	50.0
March	24+	24+	24+	1,200.0	48.0
April	24+	24+	24+	1,200.0	56.0
May	24+	24+	24+	960.0	44.7
June	22.0	21.6	22.8	370.0	36.0
July	12.0	16.9	18.0	62.0	27.3
August	14.0	10.8	12.8	46.0	24.0
September	10.3	16.8	12.9	36.0	21.0
October	20.5	20.0	16.8	56.0	22.5
November	22.1	21.7	21.4	40.0	....
December	22.6	22.1	21.8	44.0	....

a The record for this year has doubtful value.

It is evident from the estimates for the first 5 months of the year that the engineer merely wished to show that there were more than 24 second-feet flowing during the winter, and that no attempt was made to ascertain the exact amount. It is obvious that a stream which averages 14 second-feet in August or September would discharge ordinarily more than 24 second-feet in January and February. The record for 1884 has a doubtful value, although in view of the heavy rainfall it may be reasonable. The estimates for 1885 have also been called into question. The figures for 1884 have been obtained from measurements and observations made in Bear valley, at the point known as Divide, at the mouth of Santa Ana canyon. About one-half of the total amount is reported to have come from Bear valley. On August 11, 1882, there was a heavy shower in the mountains and a so-called cloudburst in Mill Creek canyon. It is reported that for over 2 hours a flood of about 1,500 second-feet ran down Mill Creek wash.

The Mojave river rises in the same area and flows northerly, its waters being finally lost in Mojave desert. Measurements of this stream have been made by Mr. F. W. Skinner, at the proposed dam site of the Victor Reservoir Company. He stated that measurements were made at frequent intervals between June 1 and August 1, 1893. The maximum discharge was 8,500 second-feet, and the minimum 38 second-feet. Surface velocity measurements only were made, these being obtained by means of floats. From the estimates thus prepared the average flow from August 1, 1892, to August 1, 1893, was computed to have been 825 second-feet. San Luis Rey river is one of the streams of San Diego county which flows from the Coast range westerly into the ocean. Its discharge has been measured by Mr. E. F. Tabor, of San Jacinto. The first measurement, that of May, 1894, amounting to 6,716 second-feet, is the extreme flood discharge as shown by high-water marks. Sweetwater river is the most southerly of the streams important in the irrigation of California. The greater part of its waters are held in storage by the Sweetwater dam, about 10 miles above the city of San Diego. Estimates of the amount of water available have been made by the engineers in charge of this work, and are given in Bulletin No. 140 of the United States Geological Survey.

MEASUREMENTS OF CALIFORNIA RIVERS.

SACRAMENTO RIVER AT RED BLUFF AND JELLYS FERRY.

(See page 44.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1894.			
December 20 (*a*)	*b*10.70	8.60	*b*45,000
1895.			
March 19 (*a*)	4.80		15,461
April 27 (*a*)	8.40	7.72	36,181
April 30	12.00	5.96	33,457
June 30	2.70	3.25	8,456
August 23	0.90	2.41	5,452
August 26 (*a*)	0.80		*d*5,500
October 5	0.70	2.66	6,046
1896.			
January 20 (*a*)	23.50	7.65	*c*136,000
January 21 (*a*)	20.80	7.60	*c*109,432
January 22 (*a*)	17.70	7.56	*c*83,558

a Measurements made at Red Bluff, others at Jellys Ferry.
b All readings at Red Bluff.
c Approximate.
d River falling.

TEJON HOUSE CREEK.

1879.			
March 3			7.5
1894.			
January 10			60.0
January 21			66.1
March 4			80.0
March 24			60.0
June 24			6.5
September 5			0.0
December 4			1.0
December 6			3.0

PASTORIA CREEK.

1894.			
March 24			14.3
June 12			3.7
July 1			2.5
September 5			0.0
November 1			0.0
December 8			26.0
1895.			
January 1			0.8
February 1			2.8
November 13			0.4
September 1			0.0

KINGS RIVER AT KINGSBURG AND AT SUSPENSION BRIDGE.

(See page 47.)

1895.			
January 10	6.00	0.92	*e*1,830
March 23	4.10	0.39	*e*500
June 25	13.20	5.38	*f*10,300
September 2	*g*9.50	2.50	*f*524
November 24	3.80	0.93	248
December 2	3.25	0.69	*e*356

e Measurements made at Kingsburg railroad bridge.
f Measurements made at Suspension bridge.
g Height at Red mountain, 4.32 feet.

SAN JOAQUIN RIVER AT HERNDON. (See page 47.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
January 9	4.00	1.07	1,905
March 22	3.85	1.60	1,937
May 5	6.65	3.28	7,419
June 23	8.00	4.05	11,225
August 31	3.00	0.68	677
October 11	2.60	0.45	332
November 25	2.55	0.38	270

TUOLUMNE RIVER AT MODESTO AND LAGRANGE. (See page 82.)

1895.			
January 8	7.70	2.01	3,003
March 21	6.90	1.76	2,429
May 1	10.25	2.55	6,078
May 2	12.90	4.37	13,546
June 27	13.00	3.01	9,308
August 27	4.00	0.41	294
August 29	4.40	3.20	*h*299
September 14	5.80	2.41	*h*1,827
October 8	4.05		*i*110
November 28	4.20	*j*0.68	*k*129
November 30	3.40	*j*0.39	213

h Measurements at Lagrange bridge.
i Computation based on length of time required to fill reservoir.
j Velocities too low to obtain accurate results.
k Measurements at Lagrange dam, discharge estimated from size of openings.

STANISLAUS RIVER AT OAKDALE. (See page 83.)

1895.			
May 3	8.80	3.92	7,744
July 1	6.15	2.98	3,754
August 28	2.40	1.39	279
October 10	2.11	1.13	192
November 29	2.12	0.99	147

MOKELUMNE RIVER AT LODI. (See page 79.)

1895.			
January 6	12.25	1.04	1,063
March 20	8.00		1,068
August 27	1.33	0.78	91

SAN LUIS REY RIVER. (See page 76.)

1894.			
May			6,716
October			4
December 8			10
December 20			240
1895.			
January 15			5,000
March 8			152
April 11			100
April 17			72
May 10			39
May 19			19

ESTIMATED MONTHLY DISCHARGE OF CALIFORNIA RIVERS IN SECOND-FEET.

SACRAMENTO RIVER AT RED BLUFF BRIDGE. (See page 44.)

(Drainage area, 9,356 square miles.)

MONTH.	Maximum.	Minimum.	Mean.
1893.			
January	123,000	15,220	47,267
February	65,600	13,860	26,792
March	85,360	15,220	32,517
April	33,880	26,670	29,566
May	48,600	16,840	30,238
June	18,600	9,040	12,764
July	9,040	6,150	7,235
August	6,150	5,990	6,057
September	10,820	5,830	6,321
October	6,285	5,910	5,980
November	6,690	5,910	6,046
December	36,880	6,150	10,095
Per annum	123,000	5,830	18,390

TEJON HOUSE CREEK AT TEJON RANCH HOUSE.

(Drainage area, 17 square miles.)

1895.			
January	93.0	5.0	13.6
February	44.0	7.0	26.1
March	33.0	11.0	19.0
April	49.5	16.3	24.7
May	34.0	9.0	18.3
June	8.0	3.1	5.2
July	3.0	1.2	2.0
August	1.5	1.2	1.3
September	1.6	1.6	1.6
October	4.0	2.0	2.7

KERN RIVER AT FIRST POINT OF MEASUREMENT. (See page 51.)

(Drainage area, 2,345 square miles.)

1893.			
October	554	517	534
November	559	467	518
December	590	430	516
1894.			
January	741	562	661
February	1,114	604	717
March	1,443	762	1,001
April	1,892	1,209	1,493
May	2,208	1,228	1,607
June	1,710	871	1,085
July	1,051	400	700
August	549	256	335
September	382	172	248
October	363	224	279
November	268	230	244
December	805	234	470
Per annum	2,208	172	737
1895.			
January	1,616	473	809
February	4,762	675	1,252
March	3,604	987	1,374
April	3,897	1,911	2,724
May	5,384	3,100	4,369
June	3,721	2,174	2,906
July	2,063	867	1,482
August	1,073	354	629

SAN JOAQUIN RIVER, HERNDON. (See page 47.)

(Drainage area above Hamptonville, 1,637 square miles.)

MONTH.	Maximum.	Minimum.	Mean.
1895.			
January	11,225	1,260	2,881
February	8,500	909	2,568
March	9,318	1,554	2,779
April	9,863	3,354	5,834
May	19,960	5,100	13,124
June	14,565	7,250	10,674
July	8,600	2,148	4,528
August	2,301	793	1,417
September	8,500	260	1,085
October	1,200	260	420
November	426	260	362
December	677	260	373
Per annum	19,960	260	3,791

TUOLUMNE RIVER AT MODESTO. (See page 82.)

(Drainage area, 1,501 square miles at foothills.)

1895.			
January	16,130	1,398	4,828
February	19,650	1,322	3,915
March	10,783	1,710	3,165
April	10,012	3,255	5,824
May	16,000	6,097	11,798
June	12,530	5,616	9,163
July	6,692	1,550	3,831
August	1,550	285	848
September (*a*)	5,616	200	615
October (*a*)	200	120	152
November (*a*)	500	210	255
December	730	180	283
Per annum	19,650	120	3,719

a Water below bottom of rod. Quantities are approximated.

TUOLUMNE RIVER, LAGRANGE BRIDGE.

(Drainage area, 1,501 square miles.)

1895.			
September	2,182	78	262
October	290	78	134
November	129	112	113
December	1,004	129	270

STANISLAUS RIVER, OAKDALE. (See page 83.)

(Drainage area, 1,051 square miles.)

1895.			
June	8,510	3,842	5,686
July	3,842	550	1,778
August	550	145	330
September	3,161	145	638
October	246	145	176
November	179	179	179
December	414	145	198

ESTIMATED MONTHLY DISCHARGE OF CALIFORNIA RIVERS IN SECOND-FEET—Continued.

SAN GABRIEL RIVER AT MOUTH OF CANYON. (See page 57.)

(Drainage area, 220 square miles.)

MONTH.	Maximum.	Minimum.	Mean.
1894.			
May	50	27	32.2
June	27	17	22.7
July	17	9	12.3
August	27	10	14.3
September	23	13	15.0
October	16	13	13.7
November (a)	14	13	13.1

a Observations from November 1 to 15, inclusive, only.

SAN GABRIEL RIVER AT MOUTH OF CANYON—Continued.

(Drainage area, 220 square miles.)

MONTH.	Maximum.	Minimum.	Mean.
1895.			
August (b)	47	38	41.8
September	39	29	32.4
October	32	27	29.4
November	50	29	40.3
December	54	37	41.7

b Observations from August 8 to 31, inclusively, only.

COLORADO.

River measurements in this state have been carried on to a large extent by the state engineer and the results are to be found in the biennial reports of that officer. Most of the investigations of this character have been confined to the South Platte and its tributaries. The United States Geological Survey has maintained measurements on the head waters of Arkansas river and of Rio Grande since 1889. During 1895 co-operation was secured between this survey and the state engineer, by which the river measurements were consolidated and extended, the work being under the direct charge of Mr. F. Cogswell.

In the Platte River basin measurements have been made of South Platte river at Deansbury, a point in the canyon about 27 miles from Denver, this being above the head of the principal canals diverting water from the river. A series of measurements has also been made at the city of Denver at a point between the Fifteenth and Sixteenth streets viaducts, this being below the mouth of Cherry creek. Measurements have also been made of tributaries to the South Platte, these being on Bear creek in the vicinity of Morrison, on South Boulder creek below South Boulder canyon, and on Boulder creek near Boulder; also on St. Vrain river near Lyons and on Big Thompson creek at Home Supply dam, 9 miles west of Loveland. The fluctuations of water in Cache la Poudre river have been carefully observed under the directions of Prof. L. G. Carpenter at the agricultural college at Fort Collins, Colo., and computations made of the daily discharge. He has also conducted a thorough series of measurements showing the amount of water returning to this stream by seepage, and has demonstrated the increase of water at lower points by early irrigation of lands above. The results of his investigations have been published as Bulletin No. 33 of the State Agricultural College Experiment Station, under the title "Seepage and return waters from irrigation". The South Platte river itself has been measured at a point near Orchard, Colo., a town about 80 miles northeasterly from Denver.

The Arkansas river is one of the streams whose fluctuations have been most thoroughly examined by the United States Geological Survey. A general description of the work along this river can be found in the reports of the irrigation survey, published as portions of the Eleventh, Twelfth, and Thirteenth Annual Reports of the United States Geological Survey. Observations have been made at Granite, below Leadville, and also at Hayden 4 miles further down, this being below the mouth of Twin Lake creek, the outlet of Twin lake. The longest series of measurements is that at Canyon city, this point being at the mouth of the Grand canyon of the Arkansas, and above most of the large irrigating systems. The river has also been measured at Pueblo, at the city bridges, giving the amount of water available for irrigation of points below. The discharge has also been ascertained at La Junta, Colo., this being below the head of most of the large irrigating canals. Observations have also been conducted for a time at the railroad bridge crossing Arkansas river, east of Granada and west of Holly, Colo. At this latter point the channel is very broad and sandy, and through a great part of the year is dry or contains small rivulets meandering from side to side, making the determinations of the discharge from Colorado into Kansas a matter of considerable difficulty and expense. Measurements have also been made farther down the river at Hutchinson, Kan., as described under the rivers of that state.

The discharge of the Rio Grande has been measured at Del Norte, at Alamosa, and also at points in New Mexico, as given under the description of that territory. The station at Del Norte is about 2 miles above the town at a locality chosen in 1890 by the irrigation survey. The computations of results at this point are among the longest series obtained in the arid regions. The point of measurement is above the head of all of the large canals of the San Luis valley, a few ditches being taken out above this point, but not perceptibly diminishing the flow of the river. The point of measurement at Alamosa is at the wagon bridge north of town. This is below most of the large canals of the valley, and the result of measurements gives merely the seepage or excess water from the irrigated lands.

The western part of the state drains into the great Colorado river. As a rule the water supply is large and in most of the streams is greater than needed by the lands lying within the narrow valleys. Measurements have been made on a number of the streams, especially in the southwestern corner of the state. The most northerly point of measurement is that at White River city on White river. Grand river is one of the principal tributaries of the great Colorado river. Measurements have been made on the main stream at Grand Junction above the mouth of Gunnison river, and also on Gunnison river near this point, and on Uncompahgre river at Fort Crawford. The amount of water in these streams as a rule is large, and in excess of the demands that will probably be made upon it, except in the Uncompahgre river where there is often scarcity.

San Miguel river, which flows northwesterly and enters Dolores river has been measured near its head waters at Seymour, Colo., and also Dolores river, at the town of Dolores. The extreme southeastern corner of the state sheds its water into San Juan river, which flows in a general westerly course through northern New Mexico and finally enters the Colorado in southeastern Utah. The discharge of a number of its tributaries has been ascertained, the principal of these being Piedra, at Arboles, a short distance above its mouth, and also the San Juan river itself above the point where Piedra river joins it. To the west of these is the Rio Florida, which enters Las Animas river from the east, about 12 miles south of Durango. On June 20, 1895, this stream was discharging about 75 second-feet at Florida. It is reported that all the water was used for irrigation during the dry season. Rio de los Pinos, a tributary of the San Juan east of Rio Florida, was examined at Ignacio. The discharge in June, 1895, was between 100 and 200 second-feet, a large amount of water being diverted above this point. Rio La Platta was examined at Hesperus and found to be carrying about 60 second-feet. Mancos river at Mancos was also flowing about 60 second-feet, much water being taken out above this point. A series of measurements have been made on Rio Las Animas at Durango.

MEASUREMENTS OF COLORADO RIVERS.

SOUTH PLATTE RIVER AT DEANSBURY. (See pages 114, 125.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
November 30	4.00	4.03	197
December 1	3.20	3.78	102
December 7	3.60	3.59	160
December 8	3.65	3.71	166
December 14	3.80	3.88	183
December 20	3.35	3.51	135
1896.			
January 6	3.60	2.15	183
January 12	3.05	2.77	94
January 18	3.05	2.80	94
January 27	2.90	2.86	90
February 4	3.18	3.29	116
February 11	3.10	3.02	101
February 19	2.97	2.84	91
February 23	3.42	3.58	144
March 18	3.07	3.01	97
March 20	3.75	3.89	184
March 30	5.15	5.51	372

SOUTH PLATTE RIVER AT DENVER. (See page 109.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
May 7	1.10	1.48	168
July 23	5.40	3.36	1,490
August 7	4.60	3.33	876
August 22	3.90	2.75	447
November 9	4.30	2.56	430
November 29	3.90	2.37	303

BEAR CREEK AT MORRISON. (See page 114.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
May 18	0.90	2.17	47
June 12	2.05	4.77	331
July 24	1.65	2.96	171
October 9	1.05	2.15	64

SOUTH BOULDER CREEK AT SOUTH BOULDER CANYON.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
May 14	2.00	3.09	164
July 18	2.00	3.19	196
October 10	1.05	1.68	42

BOULDER CREEK NEAR BOULDER.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
July 17	1.90	3.80	317
October 13	0.50	1.04	36

ST. VRAIN RIVER AT LYONS, COLO. (See page 103.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
May 11	1.65	3.33	260
July 20	3.40	3.27	336
October 2	2.10	2.78	65

MEASUREMENTS OF COLORADO RIVER—Continued.

BIG THOMPSON CREEK AT HOME SUPPLY DAM. (See pages 116, 118.)

Date.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
May 11	1.25	2.17	260
July 19	1.90	3.59	490
October 1	0.45	0.75	42

SOUTH PLATTE RIVER NEAR ORCHARD. (See page 133.)

Date.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
November 20	4.00	2.53	829
December 22	3.85	2.34	667

ARKANSAS RIVER AT GRANITE.

Date.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
July 3	0.50	5.49	1,065
September 26	3.10	2.55	215

ARKANSAS RIVER AT HAYDEN. (See page 116.)

Date.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1894.			
September 24	1.20	1.93	114
October 16	1.24	2.00	91

ARKANSAS RIVER AT CANYON CITY. (See page 111.)

Date.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1893.			
September 22	2.45	2.26	291
1894.			
May 15	4.20	7.28	2,295
May 18	3.80	6.71	1,940
June 18	4.80	6.10	2,387
September 20	2.65	2.86	395
October 15	2.40	2.56	319
1895.			
June 13	4.50	6.73	2,397
October 4	2.70	3.70	585

ARKANSAS RIVER AT PUEBLO. (See page 126.)

Date.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1894.			
April 24	(a)	1.95	322
September 19	0.35	2.50	378
October 13	0.39	2.36	370
1895.			
February 6	0.40	2.75	411
May 20	1.65	4.78	1,435
June 3	(b)	5.30	2,261
June 4	(c)	3.18	1,973
Do	(d)	5.46	2,022
June 11	2.80	6.89	2,758
September 5	0.70	3.35	570

a Measurement made at Main street bridge.
b Measurement made at Swallows.
c Measurement made at Bridge No. 3, section poor.
d Measurement made at Bridge 155 B.

ARKANSAS RIVER AT LA JUNTA.

Date.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
February 6	1.95	1.90	182
May 19	1.90	2.23	653
December 2	1.50	1.61	455

RIO GRANDE AT DEL NORTE. (See page 128.)

Date.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1891.			
April 10	3.20	2.35	527
1892.			
October 27	1.58	1.14	274
1894.			
June 13	2.68	....	968
September 27	1.52	2.32	267
1895.			
June 14	4.00	5.88	2,818
October 13	1.80	2.53	414

RIO GRANDE AT ALAMOSA. (See page 107.)

Date.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1894.			
September 28	....	1.01	10
1895.			
June 16	5.18	2.08	1,176
October 14	....	1.19	92

WHITE RIVER AT WHITE RIVER CITY. (See page 127.)

Date.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
May 16	13.10	5.81	3,047

GRAND RIVER AT GRAND JUNCTION. (See page 112.)

Date.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1894.			
October 18	2.10	1.10	1,585
1895.			
June 27	4.03	5.77	16,500
October 1	0.82	2.04	2,059

UNCOMPAHGRE RIVER AT FORT CRAWFORD. (See pages 108, 122.)

Date.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
June 25	4.60	6.80	834
August 26	3.25	3.38	218
October 7	2.60	2.05	89
November 18	2.55	2.23	92

GUNNISON RIVER AT GRAND JUNCTION. (See page 108.)

Date.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1894.			
October 17	1.25	0.80	748
1895.			
June 28	4.74	2.94	4,178
July 17	3.60	1.99	2,642
October 1	1.95	0.78	781

SAN MIGUEL RIVER AT SEYMOUR. (See page 121.)

Date.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
June 24	4.00	4.90	512
August 27	3.20	3.08	205
October 8	2.65	2.24	61

MEASUREMENTS OF COLORADO RIVER—Continued.

DOLORES RIVER AT DOLORES. (See page 122).

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (second-feet.)
1895.			
June 22	3.50	3.40	756
August 28	2.70	2.00	163
October 9	2.50	1.51	89
November 20	2.40	1.45	75

PIEDRA RIVER AT ARBOLES.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (second-feet.)
1895.			
June 21	....	3.40	606
August 30	3.20	1.94	a235
October 11	2.90	1.47	140
November 25	2.80	1.31	115

SAN JUAN RIVER AT ARBOLES.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
June 21	7.30	3.50	1,556
August 30	6.20	1.42	387
October 11	5.80	0.86	215
November 25	5.90	0.97	252

RIO LAS ANIMAS AT DURANGO. (See page 116.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
June 18	6.50	3.55	1,893
August 29	5.80	1.30	543
October 10	5.40	1.00	328
November 24	5.20	0.89	260

a Water very muddy, affecting meter.

IDAHO.

Measurements of Idaho rivers have been described in the annual reports of the irrigation survey, the earlier field work having been done mainly in southeastern Idaho. In recent years, measurements have been conducted largely in the southwestern part of the state. During 1895 the work was in charge of Mr. V. C. Tompkins, succeeded by Mr. Gerald F. Sherman. A single station in the extreme southwestern part of the state, that at Battle creek on Bear river, has been under the charge of Prof. Samuel Fortier, of Logan, Utah, as this point is of more direct concern to the people of Utah and the locality is accessible from Logan. Boise river has been measured at the mouth of the canyon above Boise, Idaho, and also a few measurements have been made near Caldwell, computations of discharge at this latter place being continued during the low-water season in order to obtain the amount of seepage or waste waters from the Boise valley. Payette river has been measured in the vicinity of Payette, and Weiser river about 10 miles above Weiser. Observations have also been conducted on Snake river at Montgomerys ferry, below Minidoka, for the purpose of obtaining the total discharge of this large river, thus furnishing information as to the engineering features for the diversion of water upon a large scale for the arable lands bordering the Snake at points below. The discharge of Bruneau river has been estimated by Mr. Andrew J. Wiley at a point near Grand View, Idaho, near the head of the large canal being constructed at that place.

MEASUREMENTS OF IDAHO RIVERS.

BEAR RIVER AT BATTLE CREEK. (See page 154.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1891.			
April 29	3.25	....	3,072
November 22	1.60	....	721
1894.			
October 29	1.00	2.12	980
November 30	1.80	2.30	1,030
1895.			
April 6	2.68	3.38	2,092
April 15	3.00	3.57	2,380
April 29	2.93	3.50	2,268
October 14	1.40	1.97	689

BOISE RIVER ABOVE BOISE. (See pages 141, 149.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
April 20	5.00	3.42	4,770
May 11	5.30	3.76	5,562
June 24	4.60	2.71	4,115
July 18	2.80	1.98	1,708
July 26	2.40	2.20	1,552
September 7	1.75	1.75	938

BOISE RIVER AT CALDWELL.

DATE.	Gauge height. (Feet.)	Mean velocity (Feet per second.)	Discharge. (Second-feet.)
1895.			
July 28	3.80	4.00	756
August 17	3.15	2.78	226
October 16	3.35	3.05	315

PAYETTE RIVER AT PAYETTE. (See page 140.)

DATE.	Gauge height. (Feet.)	Mean velocity (Feet per second.)	Discharge. (Second-feet.)
1895.			
June 28	3.50	2.35	3,723
July 22	1.53	2.29	1,882
December 11	0.36	2.21	1,003

WEISER RIVER ABOVE WEISER. (See page 156.)

DATE.	Gauge height. (Feet.)	Mean velocity (Feet per second.)	Discharge. (Second-feet.)
1894.			
December 6	1.80	1.10	277
1895.			
April 24	4.60	2.90	2,110
May 28	4.95	2.55	2,149
June 26	2.30	1.28	400
July 23	1.70	0.54	121
July 29	1.58	0.74	141
December 10	1.65	0.80	171
1896.			
January 27	4.00	2.88	1,606

MEASUREMENTS OF IDAHO RIVER—Continued.

SNAKE RIVER AT MONTGOMERYS FERRY.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
August 9	2.80	1.59	5,413
October 23	2.28	1.45	4,593

BRUNEAU RIVER AT GRAND VIEW. (See page 155.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
August 3	1.83	0.44	50
December 21	....	0.85	127

MONTANA.

The principal river measurements in Montana have been made on streams forming the head waters of the Missouri river, and especially those within or near the Gallatin valley. This has been largely on account of the convenience and relatively small expense of carrying on work in this vicinity, and also because of the fact that there has been larger demand for information from this quarter. The field work during 1895 has been in direct charge of Prof. A. M. Ryon, of the agricultural college at Bozeman, Mont.

West Gallatin river has been measured 5 miles above Salesville, this being about 20 miles southwest from Bozeman. The point of measurement is at the iron bridge and is below the head of two canals, so that the quantity of water found at this point is somewhat less than the total available for irrigation. Middle creek, one of the most important streams coming in on the east side of Gallatin valley, has been measured at a point about 7 miles from Bozeman. Gallatin river itself has been measured a short distance above its mouth, the point where observations were taken being near the Northern Pacific Railroad Bridge crossing at Logan. Madison river has been measured also near its mouth at the railroad bridge at Threeforks, Mont. Jefferson river has been measured at Sappington, Mont., this locality being 20 miles above the point where the Jefferson joins the Madison and Gallatin to form the Missouri. The flow of this latter stream has been ascertained at the bridges a mile north of Townsend, Mont.

The following tables give the measurements made at these various points, and also the computations of maximum, minimum, and mean monthly discharge based upon these and upon the observations of river heights:

MEASUREMENTS OF MONTANA RIVERS.

GALLATIN RIVER AT LOGAN. (See page 166.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1894.			
November 17	1.11	1.82	772
1895.			
April 28	2.00	2.74	1,461
May 11	2.60	3.37	2,113
June 26	3.45	4.17	3,289
July 29	0.80	1.37	477
September 28	1.20	1.83	741

MADISON RIVER AT THREEFORKS. (See pages 170, 171.)

1893.			
August 24	0.30	2.15	1,251
1894.			
November 4	0.57	1.99	1,494
1895.			
May 12	0.80	3.28	3,114
June 27	1.00	3.49	3,287
July 30	0.10	2.18	1,693
September 29	−0.10	1.90	1,440

JEFFERSON RIVER AT SAPPINGTON. (See page 168.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1889.			
August 19	....	1.89	a202
October 15	....	2.16	b333
1893.			
August 24	....	1.83	b808
1894.			
November 14	1.06	2.76	1,952
1895.			
July 31	0.80	2.02	1,028
November 30	0.95	1.90	1,200

a Measurements made at Wil[illegible] creek.
b Measurements made 4 miles from Threeforks.

MISSOURI RIVER AT TOWNSEND. (See pages 169, 170.)

1893.			
August 25	88.75	2.22	3,008
1894.			
November 18	89.00	2.44	3,706
June 29	91.05	4.67	10,609

ESTIMATED MONTHLY DISCHARGE OF MONTANA RIVERS IN SECOND-FEET.

WEST GALLATIN ABOVE SALESVILLE. (See page 167.)

(Drainage area, 860 square miles.)

MONTH.	Maximum.	Minimum.	Mean.
1895.			
August	1,322	913	1,068
September	1,112	706	835
October	771	474	603
November	645	300	441
December	424	352	393

GALLATIN RIVER AT LOGAN. (See page 166.)

(Drainage area, 1,620 square miles.)

MONTH.	Maximum.	Minimum.	Mean.
1895.			
March	....	....	a950
April	1,656	953	1,162
May	3,548	1,814	2,407
June	3,904	1,866	2,537
July	2,868	436	1,051
August	664	352	480
September	820	592	722
October	826	664	792
November	820	592	712
December	664	523	610

MIDDLE CREEK.

(Drainage area, 55 square miles.)

MONTH.	Maximum.	Minimum.	Mean.
1895.			
August	....	....	58
September	....	....	50
October	....	....	51
November	....	....	46

MADISON RIVER AT THREEFORKS. (See pages 170, 171.)

(Drainage area, 2,420 square miles.)

MONTH.	Maximum.	Minimum.	Mean.
1895.			
January	....	....	a2,310
February	....	....	a2,310
March	....	....	a2,310
April	2,880	1,980	2,214
May	3,880	2,880	3,166
June	3,480	2,680	3,163
July	2,680	1,440	1,882
August	....	....	a1,440
September	....	....	a1,440
October	....	....	a1,541
November	....	....	a1,500
December	....	....	a1,500

a Approximate.

NEVADA.

In this state investigations were carried on by the irrigation survey mainly upon the Truckee and Carson rivers. During 1895 field work has been under the immediate charge of Mr. L. H. Taylor and the number of river stations has been increased, observations being extended to the Humboldt and Walker rivers. On Truckee river the principal point of measurement is at the head of the stream near the outlet of Lake Tahoe. Here a series of observations have been maintained at the dam built to regulate the outflow of this large natural reservoir. On Carson river the point of measurement has been at the Brunswick dam near Empire, this being below Carson and Eagle valleys and above the narrow valley through which the river flows to Carson plains. The station is about 5 miles below the one established in 1889–1890, the river at this latter point not receiving the drainage of Eagle valley. On Walker river the measurements have been made at a point about one-half mile below the junction of East and West Walker rivers, and 1 mile below the town of Nordyke in Mason valley. Very little has been known concerning the actual volume delivered by this stream. It is, however, of great importance to the development of the state, as there are probably more than 300,000 acres of land among the best in this part of the country. As yet only small portions of these lands are watered, and as the Walker river is the only source from which a supply can be had, it is especially desirable to obtain accurate data concerning this stream.

Humboldt river drains the northern part of the state of Nevada. It rises in the extreme northeastern corner and flows in a general westerly course across the state to Humboldt sink, where its waters are lost by evaporation. Measurements have been made at Elko, near its headwaters; at Golconda, about halfway down, and at Oreana, a short distance above Lovelocks. In 1890 all of the diversion dams in this river in the neighborhood of Lovelocks were washed out. Computations were made at that time by Mr. Taylor and an estimate was prepared showing that the discharge at the time one of these dams went out was 4,252 second-feet, the flow being probably greater a short time after. In August, 1892, the high-water line indicated a discharge of 2,642 second-feet. On August 25 the float measurements gave a discharge of 340 second-feet; on April 20, 1893, the discharge was ascertained to be 761 second-feet; and on June 7, 1893, it was 3,054 second-feet, the water rising for sometime after this last measurement. This river, like many of the others of the arid region, is much smaller near its mouth than it is higher up. Probably it is largest about 150 miles by railroad above Lovelocks. The station at Elko is at the wagon bridge, about 1 mile southwest of the town. Measurements of discharge here furnish data as to the outflow from a considerable area within which a number of records of precipitation are being kept. The point of measurement at Golconda is 1½ miles northwest from the town. Mr. Taylor states that the exceedingly small run off at Golconda during 1895 is due to the fact that this was an excessively dry year, and also to the large area, 10,780 square miles, which must be considered as tributary to this basin. From a large portion of this tract no water came to the stream during the past dry season. It is estimated that the loss by evaporation alone from the river between Rock creek, the last important tributary, and Golconda for the month of June was 30 second-feet, and during July and August 50 second-feet. The measurements at Oreana are made at a point about 12 miles above Lovelocks, this being above all of the irrigating ditches supplying the lands in this vicinity. It is 25 miles from Humboldt lake.

MEASUREMENTS OF NEVADA RIVERS.

WALKER RIVER AT NORDYKE. (See page 187.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
June 27	3.95	3.84	2,228
July 23	2.30	2.74	817
August 21	....	1.50	177
September 29	0.60	1.55	120

HUMBOLDT RIVER AT ELKO. (See pages 185, 186.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
June 17	1.50	2.50	186
July 13	0.80	1.14	48
September 5	0.30	0.25	4
December 14	0.55	0.62	19

HUMBOLDT RIVER AT GOLCONDA.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1894.			
October 24	1.30	1.29	57
December 4	2.00	1.31	114
1895.			
March 22	3.82	2.12	463
June 21	2.55	1.35	204
July 12	1.62	1.15	96
August 12	0.05	0.91	11
September 8	−0.30	1.20	0.96
1896.			
January 26	1.00	0.92	55
February 10	1.52	1.35	93

ESTIMATED MONTHLY DISCHARGE OF NEVADA RIVERS IN SECOND-FEET.

HUMBOLDT RIVER AT GOLCONDA.

(Drainage area, 10,780 square miles.)

MONTH.	Maximum.	Minimum.	Mean.
1894.			
October 24 to 31	65	57	60
November	115	67	90
December	147	57	117
1895.			
January	162	106	141
February	385	127	175
March	630	362	478
April	1,035	622	913
May	842	568	672
June	568	153	353
July	153	35	80
August	28	1.60	12
September	2.00	0.70	0.93
October	0.96	0.70	0.82
November	9.00	0.96	1.80
December	11.50	9.80	10.96

HUMBOLDT RIVER AT ELKO, NEV., FOR 1895.

(Drainage area, 2,840 square miles.)

MONTH.	Maximum.	Minimum.	Mean.
1895.			
June 17 to 30	186	107	139
July	241	24	72
August	24	4	13
September	8	4	5
October	22	5.40	15
November	34	1.50	24
December	48	24	31

CARSON RIVER AT BRUNSWICK. (See page 183.)

MONTH.	Maximum.	Minimum.	Mean.
1895.			
June 25 to 30	1,980	1,645	1,804
July	1,565	244	802
August	294	63	149
September	407	107	192
October	237	77	154
November	259	124	204
December	840	63	211

WALKER RIVER AT NORDYKE. (See page 187.)

MONTH.	Maximum.	Minimum.	Mean.
1895.			
June 27 to 30	2,591	2,228	2,448
July	1,983	474	1,179
August	398	127	235
September	500	101	170
October	353	107	180
November	227	227	227
December	242	227	228

NEW MEXICO.

Measurements of rivers in New Mexico have been confined mainly to the Rio Grande and its tributaries, the principal exception being in the case of a station established on Mora river, one of the head waters of Canadian river, at a point near the railroad station at Watrous, N. Mex. During the later part of 1895 the field work in this territory has been under the immediate direction of Mr. P. E. Harroun, of Santa Fe. The most northerly station maintained by him has been at the railroad station of Embudo, on the Rio Grande, a short distance above the point where it leaves the narrow canyons through which it has flowed after leaving Colorado. The measurements at this point give the total amount draining from this upper catchment basin and furnish data as to the amount available for the Espanola valley and for lower areas. In this valley the Rio Grande is joined by Chama river coming in from the northwest. The volume of this stream, though less than that of the upper Rio Grande, is relatively large for this portion of the country. The river station on the Chama is at Abiquiu, about 20 miles above its mouth. A third point of measurement has been chosen at a point below the mouth of the Chama, this being at the lower end of the Espanola valley, above the point where the river cuts through White Rock canyon to enter again upon the broad valley extending below Albuquerque. This place is at the bridge of the railroad crossing the Rio Grande at a locality known as Watertank, or Rio Grande.

Measurements of the Rio Grande are also made at San Marcial, near the railroad bridge of the Atchison, Topeka and Santa Fe railroad, and the stream is measured for the last time at El Paso, just before it becomes a portion of the international boundary. At this lower part of its course the river is dry through a great part of the year and at other times is a torrent of turbid waters, the channel shifting rapidly, cutting out the mud banks at one place and redepositing them at another. The following tables give the results of measurements made at the points mentioned above, and also the estimated monthly discharge computed from these figures.

MEASUREMENTS OF NEW MEXICO RIVERS.

MORA RIVER AT WATROUS.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1894.			
October 4	1.68	1.05	35
1895.			
May 18	1.50	0.89	18
July 15	2.00	0.85	131
September 4	2.30	1.49	180
September 30	1.50	0.66	15
November 16	1.90	0.86	39
December 13	1.90	1.01	61

CHAMA RIVER AT ABIQUIU. (See page 199.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
June 21	2.50	1.59	404
July 25	2.90	1.33	206
August 18	1.30	1.77	200
October 29	1.10	1.31	72
November 26	1.80	0.64	77

RIO GRANDE AT EMBUDO. (See page 199.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1891.			
April 7	9.42	2 91	1,314
December 10	6.50	1.50	575
1892.			
October 30	7.80	0.98	333
October 30	7.80	0.86	313
November 1	7.80	0.95	355
1894.			
September 30	7.70	1.50	284
October 1	9.30	3.25	1,138

RIO GRANDE AT EMBUDO. (See page 199.)—Continued.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.	Discharge. (Second-feet.)
1895.			
February 2	7.98	2.23	464
February 4	8.01	2.25	453
April 8	9.40	2.94	1,175
May 14	11.20	4.39	3,219
July 27	9.90	3.88	1,669
August 19	8.80	2.34	908
October 26	8.10	1.65	494
November 28	8.40	1.82	617

RIO GRANDE AT RIO GRANDE OR WATERTANK.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.	Discharge. (Second-feet.)
1895.			
February 1	4.60	3.11	652
April 19	9.80	6.55	5,174
May 11	8.00	5.86	4,249
June 5	9.10	5.86	6,689
July 23	6.60	4.41	2,095
August 21	5.50	3.92	933
September 10	5.10	3.43	739
October 24	4.90	2.23	629
November 30	4.90	2.84	639

RIO GRANDE AT SAN MARCIAL.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.	Discharge. (Second-feet.)
1889.			
August 8	1.60	....	19
1895.			
January 29	6.40	0.38	89
April 22	9.50	6.07	7,805
May 19	7.60	5.49	3,458
June 1	8.60	4.12	4,714

MEASUREMENTS OF NEW MEXICO RIVERS—Continued.

RIO GRANDE AT SAN MARCIAL—Continued.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.	Discharge. (Second feet.)
1895.			
July 18	6.60	2.36	1,508
September 5	6.90	1.90	626
October 1	5.30	1.47	15
November 17	7.20	2.17	674
December 14	7.20	3.12	602
1896.			
January 10	7.40	3.20	701
January 22	7.50	3.29	767
February 14	7.30	3.63	570

RIO GRANDE AT EL PASO, TEX. (See page 197.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
January 25	6.40	0.87	230
July 19	8.10	0.71	1,039
September 6	7.90	1.63	751
October 3	5.70	0.23	26
November 21	6.90	1.55	392
December 4	7.50	1.57	423
December 16	6.80	1.13	266
December 21	7.42	1.50	338

ESTIMATED MONTHLY DISCHARGE OF NEW MEXICO RIVERS IN SECOND-FEET.

RIO GRANDE AT EMBUDO, 1895. (See page 199.)
(Drainage area, 7,000 square miles.)

MONTH.	Maximum.	Minimum.	Mean.
January	552	433	475
February	672	420	503
March	1,410	640	759
April	4,290	592	2,541
May	4,290	1,573	2,679
June	4,965	790	3,021
July	2,530	612	1,335
August	2,016	652	1,080
September	1,146	480	636
October	572	460	494
November	700	540	611
December	580	420	534

RIO GRANDE AT WATERTANK, 1895.

MONTH.	Maximum.	Minimum.	Mean.
February	1.440	355	591
March	2,640	730	1,371
April	8,630	1,610	5,073
May	6,055	2,420	4,616
June	7,200	1,120	4,630
July	4,430	1,005	1,768
August	2,490	705	1,481
September	1,160	530	723
October	880	630	707
November	940	655	834
December	855	605	713

OREGON.

The investigations of water supply of Oregon have been confined to the extreme eastern end, in the vicinity of Boise, Idaho. Measurements have been made of two rivers, the Malheur and Owyhee. The station on the Owyhee is near the mouth of the river, while that on the Malheur is near Vale, and at a point above most of the lower irrigating ditches.

MEASUREMENTS OF OREGON RIVERS.

OWYHEE RIVER AT NYSSA. (See page 215.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
May 25	2.40	1.12	773
June 30	1.30	0.60	213
July 20	1.00	0.54	64

MALHEUR RIVER AT VALE. (See page 214.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
April 26	3.00	0.74	521
May 24	2.10	0.70	261
June 29	0.80	0.63	28
July 21	0.58	0.97	9

UTAH.

Measurements for water supply in this state have been mainly under the charge of Prof. Samuel Fortier, of Logan, Utah. He has maintained the river stations previously located by the irrigation survey, and has carried on measurements at other localities. The principal streams examined have been: on the north, the Bear, and south of this the Ogden, Weber, and Provo. Bear river has been measured at two points, the first at Battle Creek, Idaho, at a point above where the river enters Cache valley, Utah. The results obtained at this place are described above under the head of Idaho. The second point on Bear river is at Collinston, in the canyon through which Bear river flows from Cache valley to Salt Lake valley, this being below the head works of the Bear River canal. Ogden river has been measured in Ogden canyon about 7 miles east of the city of Ogden. Prof. Samuel Fortier has also made a very thorough series of measurements of return waters and increase of flow of this stream by seepage from irrigated lands in the upper valleys. Weber river has been measured about 10 miles easterly from Ogden, near what is known as Devils Gate on the Union Pacific Railroad, 5 miles east of Uinta. The flow of Provo river has been obtained at a point in the canyon about 6 miles from the city of Provo, this being above most of the irrigating ditches. The results of measurements made on these rivers are given in the following tables, and also computations of maximum, minimum, and mean monthly discharge.

MEASUREMENTS OF UTAH RIVERS.

BEAR RIVER AT COLLINSTON. (See page 223.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1891.			
April 27	4.90	3.84	4,859
November 24	2.25	2.14	1,192
1893.			
September 2	1.70	1.40	715
1894.			
October 6	2.01	2.61	1,800
December 22	2.10	2.57	1,875
1895.			
April 8	a3.16	3.01	3,041
April 15	3.75	3.44	3,853
April 22	3.58	3.27	3,453
April 29	3.61	3.27	3,460
August 19	1.17	2.15	819
September 23	1.62	2.14	1,058
December 9	1.95	2.21	1,397

a New gauge.

WEBER RIVER AT UINTA. (See page 235.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1889.			
August 12	....	1.00	a33
October 17	0.70	2.02	130
1890.			
May 3	5.40	7.01	4,330
May 19	5.90	7.14	4,804
July 21	1.60	3.12	590
August 12	1.10	2.35	254
September 4	1.00	2.20	220
1891.			
April 23	3.40	5.81	2,184
November 27	1.40	3.24	402

a Measurement made at county bridge near Uinta.

WEBER RIVER AT UINTA—Continued.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.	Discharge. (Second-feet.)
1894.			
July 20	a1.10	2.84	298
August 15	0.50	1.73	141
1895.			
January 28	b0.85	1.31	168
June 17	2.20	4.04	955
July 23	1.20	1.93	222
August 17	0.85	1.40	100
September 14	0.85	1.37	94
November 5	1.41	2.25	274

a New gauge; reading of old gauge, 1.20.
b Ice in river makes this of doubtful value.

OGDEN RIVER, NEAR OGDEN. (See page 235.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
June 13	2.02	1.43	150
September 13	1.45	1.09	67
October 14	1.53	1.20	73
November 11	1.55	1.26	71

PROVO RIVER ABOVE PROVO. (See page 233.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1894.			
December 24	4.40	2.53	390
1895.			
June 15	4.80	3.69	680
July 20	4.10	2.19	277

PRICE RIVER AT HELPER.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
July 1	....	1.80	119

ESTIMATED MONTHLY DISCHARGE OF UTAH RIVERS IN SECOND-FEET.

BEAR RIVER AT BATTLE CREEK.

(Drainage area, 4,500 square miles.)

Month.	Maximum.	Minimum.	Mean.
1895.			
January	993	908	922
February	993	908	911
March	2,977	826	1,095
April	2,717	1,839	2,268
May	3,637	2,717	2,086
June	2,887	1,375	1,932
July	1,600	750	967
August	750	612	658
September	680	612	628
October	680	612	666
November	680	680	680
December	680	680	680
Per annum	3,637	612	1,207

BEAR RIVER AT COLLINSTON.

(Drainage area, 6,000 square miles.)

Month.	Maximum.	Minimum.	Mean.
1895.			
January	1,680	1,570	1,610
February	1,800	1,455	1,630
March	4,460	1,350	2,030
April	3,945	1,920	3,244
May	4,990	3,685	4,329
June	3,685	1,512	2,027
July	1,455	540	961
August	980	750	813
September	1,155	750	873
October	1,250	1,155	1,192
November	1,455	1,250	1,341
December	1,455	1,455	1,455
Per annum	4,990	540	1,842

OGDEN RIVER, ABOVE OGDEN.

Month.	Maximum.	Minimum.	Mean.
1895.			
June 14 to 30	130	94	105
July	111	57	85
August	63	52	56
September	63	52	57

OGDEN RIVER ABOVE OGDEN—Continued.

Month.	Maximum.	Minimum.	Mean.
1895.			
October	67	62	65
November	73	67	71
December	73	58	68

WEBER RIVER AT UINTA.

(Drainage area, 1,600 square miles.)

Month.	Maximum.	Minimum.	Mean.
1895.			
January	196	90	146
February	280	112	138
March	1,080	165	279
April	2,400	770	1,512
May	2,400	955	2,007
June	1,300	190	849
July	390	112	188
August	196	112	154
September	232	135	187
October	280	232	278
November	337	337	333
December	390	337	339
Per annum	2,400	90	534

PROVO RIVER AT PROVO CANYON.

(Drainage area, 640 square miles.)

Month.	Maximum.	Minimum.	Mean.
1895.			
January	508	292	341
February	389	292	326
March	968	292	421
April	1,050	444	683
May	1,760	968	1,216
June	968	292	542
July	292	220	261
August	220	192	215
September	254	192	209
October	254	254	254
November	338	292	300
December	338	292	303
Per annum	1,760	192	423

WASHINGTON.

Estimates of the available water supply of this state have been confined mainly to the streams of the Yakima valley. Yakima river rises among the summits of the Cascade range and flows in a general southeasterly and southerly course into Columbia river. Among the mountains are many lakes adapted for storage purposes, and taken as a whole the water supply is one of the best and most easily controlled in this part of the country. The outflow of Lake Kahchass was measured at a point about 2 miles northerly from the railroad station of Easton. This lake is about 9 miles in length and from 1.5 to 2 miles wide. On August 16, 1893, at time of low water, it was discharging approximately 211 second-feet. The Yakima river, after receiving the waters of this lake region, flows through a number of valleys in succession, in each of which the water is diverted for irrigation. Its largest tributary is the Naches, coming in from the west above the town of North Yakima. Measurements have been made at this point, and also of Yakima river farther down at Union Gap, below the old town of Yakima. The lowest point on the river at which measurements have been made is at Kiona.

MEASUREMENTS OF WASHINGTON RIVERS.

NACHES RIVER ABOVE NORTH YAKIMA. (See page 246.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet).
1893.			
August 14	1.00	3.70	1,193
1894.			
November 21	2.50	2.44	a1,196
1895.			
August 16	1.62	1.61	466
December 2	....	1.44	349

a Measurement made at Nelsons bridge, 4 miles above mouth of river.

YAKIMA RIVER AT UNION GAP. (See page 246.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1893.			
August 14	0.90	3.09	2,963
September 26	—0.25	2.62	1,186

YAKIMA RIVER AT UNION GAP—Continued.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1894.			
November 25	....	5.74	5,026
1895.			
August 10	4.10	1.13	1,070
November 18	4.66	1.63	1,889

YAKIMA RIVER AT KIONA.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
August 20	....	1.27	954

WYOMING.

The water supply in this state is large, and the knowledge of it is considerable, through the number of measurements made by the state engineer, Prof. Elwood Mead. The results of this work are shown in the biennial reports of the state engineer, and have been noted in the annual reports of the United States Geological Survey. During 1895 the measurements were under the direct charge of Mr. W. M. Gilcrest. A few computations of discharge have been made for Big Goose creek at Sheridan, Wyo., by Mr. E. Gillette, the superintendent of water division No. 2, of Wyoming. The discharge has been computed for the point at the bridge in the northern part of the town of Sheridan. The average discharge for August and September is stated by Mr. Gilcrest to be about 275 second-feet. The amount of water at this place represents the waste or surplus from irrigation systems above. There are a few small ditches below, but for the most part the valley is narrow and bounded by Bad Lands. This stream, as well as others of the northern part of Wyoming, flows northerly, being a portion of the Yellowstone drainage, this being in turn included within the Missouri basin.

The central and southeastern part of Wyoming is drained by North Platte river. A number of measurements have been made on this stream and on its principal tributary, the Laramie. The latter rises in northern Colorado and flows across the state line into Wyoming. The discharge has been measured at a point a short distance below the state line at Woods Landing, a series of measurements being maintained at intervals through several years. Water is diverted farther downstream by a number of canals covering the Laramie plains. The river passes round or breaks through the northern end of the Laramie range, its waters being diverted at about this point and taken for irrigation in the vicinity of Wheatland. Measurements have been made at the railroad crossing at Uva below nearly all of the irrigating ditches, the amount at this point representing seepage or waste water, a part of which may be made available by storage. North Platte river has been measured at the railroad bridge near Orin Junction, this being a considerable distance above the mouth of Laramie river.

The greater portion of southwestern Wyoming is tributary to Green river. A number of measurements have been made on this stream at intervals by Prof. Elwood Mead at a point near the crossing of the Union Pacific railroad at Green River city. During 1891 observations were maintained and computations made of the daily discharge from June 10 to September 10. The results are shown on page xxx of the state engineer's report for 1894. The average discharge from June 10 to 30, 1891, was 8,743 second-feet; for July it was 6,709 second-feet; for August, 2,938 second-feet; for September 1 to 10, it was 1,624 second-feet. A single measurement of Green river above New Fork on July 21, 1894, gave a discharge of 2,427 second-feet. In the spring of 1895 the station at Green River city was re-established and observations continued at intervals, the work being under the charge of Mr. W. M. Gilcrest. The results are shown in the following tables:

MEASUREMENTS OF WYOMING RIVERS.

BIG GOOSE CREEK AT SHERIDAN.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.	Discharge. (Second-feet.)
1895.			
September 1	....	....	275

LARAMIE RIVER AT WOODS LANDING.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1894.			
September 28	....	....	a57
November 3	....	1.47	80

MEASUREMENTS OF WYOMING RIVERS—Continued.

LARAMIE RIVER AT WOODS LANDING—Continued.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
May 24	2.80	4.74	1,129
October 23	0.80	1.19	49

LARAMIE RIVER AT UVA. (See page 254.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1894.			
June 6			[a]1,845
October 24		2.06	14
1895.			
June 14	4.75	4.04	1,417
July 15	1.60	1.65	146
September 27	0.75	1.51	6

NORTH PLATTE RIVER AT ORIN JUNCTION.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1894.			
May 8			[a]6,823
June 7			12,823
August 15			816
October 26		1.42	502
1895.			
June 27	3.80	4.29	4,110
July 17	2.90	3.20	2,475
September 26	0.65	1.07	508

GREEN RIVER AT GREEN RIVER CITY.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
June 20	3.30	3.43	3,866
July 2	4.25	3.07	7,011
October 22	1.15	1.26	418

[a] Biennial report of state engineer, page xxv, 1894.

ESTIMATED MONTHLY DISCHARGE OF WYOMING RIVERS IN SECOND-FEET.

LARAMIE RIVER AT UVA.

(Drainage area, 3,179 square miles.)

MONTH.	Maximum.	Minimum.	Mean.
1895.			
April 22 to 30	542	190	283
May	1,250	350	605
June		380	
July	475	52	196
August	91	18	36
September	18	13	15
October	18	13	17
November 1 to 20	20	18	19

NORTH PLATTE RIVER AT ORIN JUNCTION.

(Drainage area, 14,828 square miles.)

MONTH.	Maximum.	Minimum.	Mean.
1895.			
July	4,405	1,378	2,397
August	1,990	647	1,038

NORTH PLATTE RIVER AT ORIN JUNCTION—Continued.

(Drainage area, 14,828 square miles.)

MONTH.	Maximum.	Minimum.	Mean.
1895.			
September	635	425	544
October	695	608	657
November	695	608	695

GREEN RIVER AT UNION PACIFIC R. R. BRIDGE.

MONTH.	Maximum.	Minimum.	Mean.
1895.			
May	6,200	2,345	3,968
June	6,915	3,600	4,547
July	7,050	2,530	4,119
August	2,735	1,005	1,704
September	980	482	638
October	608	400	472
November (1 to 8, 17 to 20)	361	230	309

SUBHUMID REGION.

In the main body of this report the arid states and territories have been described individually, while those in which the greater portion of the land is subhumid or partially arid have been grouped under a single designation. This division at the time made was a natural one, as irrigation had scarcely begun to gain a foothold in the subhumid states, and comparatively little could be said about it. Since the time of the preparation of this report on irrigation, however, there has been far greater relative progress in these subhumid states, especially in portions of western Kansas and Nebraska. The question of water supply in these states is far more difficult than that in the more arid sections of the country, from the fact that out on this great plains region there are comparatively few perennial streams, and dependence must be placed to a large extent upon wells and water storage. Various methods of raising water from under ground have been tried and many experiments conducted on a large scale to demonstrate the feasibility of pumping water. In the vicinity of Garden city, Kan., especially, there has been great progress, and in the valleys of western Kansas, where water is not far from the surface, pumps driven by windmills or by gasoline or steam engines are being used successfully by farmers. It is not possible, however, to procure water in sufficient quantities at all points, and dependence must be placed to a certain extent upon the storage of flood or storm waters in reservoirs. This brings about a consideration of the topography of the country, whether favorable or not for delivering a suitable amount of water at points where reservoirs can be constructed

The determination of practicable methods or of the best methods rests upon a thorough examination of the country, both as to its topography and underground geology, with reference to water contents. Throughout extensive tracts the underlying rocks are mainly shales impervious to water. A thorough examination and mapping of such areas will bring these facts to the attention of the public and result in the saving of thousands of dollars in experimental drillings. At other places the waters are so impregnated with saline matter that they can not be used for agricultural purposes. These facts also should be carefully ascertained and given to the public for the guidance of persons who in the future may seek to develop the resources in this way. Such localities, however, although devoid of a sufficient supply of underground water suitable for agricultural purposes, may possibly be irrigated by surface water held in suitable reservoirs. This can be ascertained only after a survey and mapping of the surface, together with a complete series of measurements of the streams found in this prairie region. Such examinations are being made by the United States Geological Survey and the results are being published in annual reports and in bulletins.

NORTH AND SOUTH DAKOTA.

In these states irrigation is dependent largely upon waters from artesian wells or from small storage reservoirs. The principal exception is in the case of the region in the vicinity of the Black Hills, where farming by artificial application of water is feasible through the number of small streams flowing from this mountainous area. In the valley of Red River of the North, and also in portions of James River valley are many small flowing wells deriving a supply of water from the glacial gravels. The principal wells of these two states, however, reach down into the water bearing sandstones, generally known to geologists under the name of Dakota. The flow of these wells is phenomenal, the quantity being extraordinary when compared with the average discharge of wells in other parts of the United States. Some of this water is slightly brackish or alkaline and must be used for irrigation with great care. These wells have been described by the state geologist of South Dakota and later by Mr. N. H. Darton in a paper accompanying the Annual Report of the Director of the United States Geological Survey.

NEBRASKA.

The principal water supply of this state at present used for irrigation is derived from North Platte river, the largest irrigating systems being along this stream, beginning near the Wyoming line. Measurements have been made at various points as shown in the following tables, the work in this state being under the direct charge of Prof. O. V. P. Stout. The measurements of flow of North Platte river at North Platte were made by Mr. Charles P. Ross. Field work has also been carried on along the various branches of the Loup river and on the head waters of Republican river and its principal tributary, Frenchman river. On Middle Loup river a series of measurements were made by Professor Stout for the purpose of obtaining data concerning the increase of discharge due to percolation from underground sources. The first of these was made at the forks of the stream about 8.5 miles above Mullen, Hooker county, Neb. From here down measurements were made near Mullen, Seneca, Thedford, Dunning, and Loup city. Below Dunning the Dismal enters the stream, but allowance has been made for its discharge in the following table of increase of flow:

MEASUREMENTS SHOWING INCREASE OF DISCHARGE OF MIDDLE LOUP RIVER FROM UNDERGROUND SOURCES, AUGUST 20 TO 29, 1895.

DATE.	Locality.	Distance between points. (Miles.)	Discharge. (Second feet.)	Increase in flow.	
				Between points. (Second-feet.)	Per mile. (Second-feet.)
1895.					
August 20	Forks	....	42	....	....
Do	Mullen	8	120	78	9.7
August 21	Seneca	11	216	96	8.7
August 22	Thedford	15	284	68	4.5
August 23	Dunning	27	322	38	1.1
Do	do	....	615	....	....
August 29	Loup city	70	879	264	3.8

Measurements of Loup river have been made at Columbus, this point being a short distance above the point where it enters Platte river, and estimates have also been made of the discharge of Platte river above the mouth of Loup river.

MISCELLANEOUS MEASUREMENTS OF NEBRASKA RIVERS.

DATE.	Stream.	Locality.	Discharge. (Second-feet.)
1892.			
September 24	Birdwood creek	Roberts ranch	126
October 8	Pumpkinseed creek	Careys ranch	32
Do.	North Platte	Camp Clarke	333
October 16	Mitchell canal	Horse creek	24
Do.	Horse creek	Mitchell flume	86
November 5	Blue creek	Town bridge	105
October 27	South Platte	Julesburg	653
November 2	do	North Platte	460
November 22	do	do	645
1894.			
September 16	Cedar creek	Fullerton	210
September 17	Beaver creek	Genoa	71
September 16	Loup river	Fullerton	1,704
1895.			
April 30	Salt creek	Lincoln	1,500
Spring	do	do	40
June 14	North Platte	Gering	11,350
June 17	do	do	10,963

MEASUREMENTS OF NEBRASKA STREAMS.

NORTH PLATTE RIVER AT NORTH PLATTE. (See page 267.)

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1892.			
September 14		1.63	770
November 2		1.62	1,070
November 22		2.32	1,370
1894.			
October 5		1.58	620
November 6		1.72	1,227
1895.			
March 27	2.22	1.88	2,329
April 29	2.90	2.16	5,695
May 28	2.90	2.43	6,320
June 8	4.00	2.85	16,261
September 14	1.30	1.64	200

NORTH LOUP RIVER AT ST. PAUL.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
May 4	3.27	2.64	1,520
June 28	3.21	2.26	1,127
September 6	3.01	2.34	816

MIDDLE LOUP RIVER AT ST. PAUL.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
June 28	1.83	1.93	1,046
September 7	1.62	1.81	863

LOUP RIVER AT COLUMBUS.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
March 29	4.77	3.75	2,790
April 21	4.65	3.41	2,303
June 12	4.55	3.39	2,835
June 29	4.50	3.27	2,715
September 7	4.17	2.58	1,896

PLATTE RIVER AT COLUMBUS.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
March 29	0.40		2,531
May 3			5,550
May 22			5,896
June 11	2.28		27,214
June 25	1.42		12,431
July 15	0.72		5,338
August 13			75

NORTH FORK OF REPUBLICAN RIVER AT BENKELMAN.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1894.			
December 9	1.74	2.31	75
March 23	1.89	2.01	73
1895.			
June 4	1.08	2.83	141
June 24	1.06	1.45	36
August 7	0.96	2.02	64

SOUTH FORK OF REPUBLICAN RIVER AT BENKELMAN.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1894.			
December 9			1
1895.			
March 23	1.89	1.70	41
June 4	(a)	2.90	348
June 24	1.50	1.79	75
July 3	2.60	2.48	278
August 7	1.75	1.30	22

[a] Old gauge washed out; new one erected June 21.

MEASUREMENTS OF NEBRASKA STREAMS—Continued.

FRENCHMAN RIVER AT WAUNETA.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
August 9	1.40	2.00	61
September 10	0.92	1.65	56

FRENCHMAN RIVER AT PALISADE.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1894.			
December 8	1.87	1.41	116
1895.			
March 22	1.52	1.00	100
June 5	1.76	1.55	154
July 4	1.61	1.50	74
August 9	1.50	1.23	68
August 10	1.50	1.69	72

ESTIMATED MEAN MONTHLY DISCHARGE OF NEBRASKA RIVERS IN SECOND-FEET.

MONTH.	North Loup river at St. Paul.	Middle Loup river at St. Paul.	Loup river at Columbus.	North Fork of Republican river at Benkelman.	Frenchman river at Palisade.	North Platte river at North Platte.
1895.						
March	....	....	....	78	....	3,005
April	....	....	2,754	50	137	3,470
May	a1,189	1,173	2,966	25	129	7,033
June	1,531	1,396	3,591	155	117	10,901
July	864	861	2,122	120	99	3,137
August	984	973	2,289	34	78	492
September	1,094	877	2,427	Dry.	74	241
October	1,146	843	2,450	....	....	610

a Twenty-seven days.

KANSAS.

In this state the development of irrigation is less dependent upon surface streams than in any other part of the country. The greatest need of water is experienced in the regions where the volume of the rivers is exceedingly small and unreliable, but there it has been found practicable to pump water from the pervious rocks or unconsolidated deposits. In many localities, however, it will not be practicable to obtain water by pumping on account of the depth at which water is reached or because of the saline character of the supply. Questions of water storage, therefore, are of considerable importance, and to determine these estimates upon the probable run off must be made. A series of stream measurements have been carried on in Kansas during 1895, the river stations being, to a large extent, located at about the ninety-eighth meridian, giving the outflow from the western and central portions of the state. The work at these points has been in charge of Mr. W. G. Russell, other stations in the southern or southeastern part of the state being under the care of Prof. E. C. Murphy, while one station, that of Manhattan, has been under the immediate supervision of Prof. O. P. Hood. The results of the measurements made at these various points are shown in the following tables:

MEASUREMENTS OF KANSAS RIVERS.

REPUBLICAN RIVER AT JUNCTION CITY.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
April 27	3.00	1.52	219
August 20	4.75	2.72	1,911
October 11	2.57	1.95	281
November 11	2.60	1.95	286
December 13	2.95	2.02	378
December 27	3.18	2.38	445

SOLOMON RIVER AT BELOIT.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
April 20	2.90	1.60	148
August 19	3.27	1.64	195
October 31	2.10	0.33	8
November 1	2.93	1.24	78
December 13	2.85	1.19	109
December 27	2.80	1.07	105

MEASUREMENTS OF KANSAS RIVERS—Continued.

SALINE RIVER AT BEVERLY.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
April 18	a1.50	1.35	22
June 8	a9.90	2.77	1,238
July 22	6.10	1.76	226
August 22	4.70	1.52	76
September 21	3.85	0.42	13
November 12	4.30	1.09	56
December 14	4.60	1.19	70
December 23	4.10	0.57	25

a Old gauge before injury by flood.

SMOKY HILL RIVER AT ELLSWORTH.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
April 16	1.50	0.84	12
April 27 (a)	....	0.33	188
June 5	9.05	2.91	5,402
July 3	2.60	1.89	217
August 21	2.10	1.34	104
September 20	1.50	0.94	26
October 23	1.35	0.84	17
December 6	1.35	0.94	18
December 28	1.30	0.95	18

a Measurement at Taylor bridge, Junction city.

BLUE RIVER AT MANHATTAN.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
April 12	3.60	1.48	542
July 11	3.70	....	....
August 17	6.90	....	....
August 24	5.70	1.61	1,512

KANSAS RIVER AT LAWRENCE.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
July 19	2.70	1.60	8,994
July 27	1.90	1.20	6,411
August 6	1.10	0.64	3,025
August 22	4.10	2.76	17,945
August 24	2.35	1.44	7,869
August 27	1.47	0.86	4,277
September 3	3.24	2.14	12,935
September 4	2.63	1.74	9,960
October 5	0.35	2.63	a1,286
October 25	1.50	1.90	a963
November 1	0.20	1.35	b376

a Measurements at Lecompton.

b Measurement of flume at Lawrence.

ARKANSAS RIVER AT HUTCHINSON.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
May 13	1.30	0.90	10
June 20	3.40	1.98	1,471
July 27	5.65	3.93	12,300
August 31	2.73	1.86	1,037
October 1	1.60	0.80	57
November 13	1.50	0.73	46
December 20	2.15	1.33	125
December 31	1.75	0.64	49

VERDIGRIS RIVER AT LIBERTY.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
August 2	2.40	0.85	107
September 7	3.44	1.59	443
November 15	2.70	1.16	218

NEOSHO RIVER AT IOLA.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
July 30	2.75	0.57	257
August 3	3.10	0.98	521
November 15	2.40	0.56	267

MEDICINE RIVER AT KIOWA.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
May 6	2.35	0.91	23
June 21	2.40	1.34	66
July 25	3.20	1.70	294
September 1	2.60	1.06	40
October 29	2.40	0.68	15
December 21	2.65	1.22	54

CIMARRON RIVER AT ARKALON.

DATE.	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.			
May 14	2.50	1.31	17
June 24	2.70	1.80	16
July 23	7.00	1.79	319
August 29	2.30	1.55	16
October 3	2.35	0.98	16

ESTIMATED MONTHLY DISCHARGE OF KANSAS RIVERS IN SECOND-FEET.

REPUBLICAN RIVER AT JUNCTION CITY.

(Drainage area, 25,837 square miles).

MONTH.	Maximum.	Minimum.	Mean.
1895.			
July	6,900	439	1,800
August	[a]78,000	265	3,192
September	4,170	219	542
October	836	220	249
November	355	230	282
December	575	230	392

[a] Estimated.

SOLOMON RIVER AT BELOIT.

(Drainage area, 5,539 square miles).

1895.			
July	[a]21,000	150	2,202
August	24,000	172	1,629
September	615	14	156
October	62	7	28
November	26	7	23
December	250	7	114

[a] Estimated.

SALINE RIVER AT BEVERLY.

(Drainage area, 2,730 square miles).

1895.			
July	[a]10,000	73	574
August	339	58	101
September	92	9	38
October	56	6	27
November	62	9	33
December	57	13	33

[a] Estimated.

SMOKY HILL RIVER AT ELLSWORTH.

(Drainage area, 7,980 square miles.)

1895.			
July	[a]21,000	202	1,438
August	344	65	186
September	135	19	44
October	22	14	18
November	19	12	17
December	22	11	17

[a] Estimated.

ESTIMATED MONTHLY DISCHARGE OF KANSAS RIVERS IN SECOND-FEET—Continued.

KANSAS RIVER AT LAWRENCE.

(Drainage area, 59,841 square miles.)

MONTH.	Maximum.	Minimum.	Mean.
1895.			
February 18 to 28	1,098	787	930
March	1,643	967	1,364
April	1,872	967	1,372
May	1,473	787	1,074
June	20,050	967	5,927
July	10,370	2,395	5,666
August	28,190	3,163	11,318
September	20,650	1,255	5,068
October	1,255	967	1,090
November	1,346	863	1,044
December	1,255	787	926

ARKANSAS RIVER AT HUTCHINSON.

(Drainage area, 34,000 square miles.)

1895			
July	19,600	444	3,884
August	8,040	958	2,712
September	1,203	57	375
October	84	37	58
November	57	29	43
December	157	37	71

MEDICINE RIVER AT KIOWA.

(Drainage area, 1,300 square miles).

1895.			
July	1,190	12	170
August	427	8	90
September	110	5	20
October	32	5	15
November	154	14	49
December	156	12	26

CIMARRON RIVER AT ARKALON.

(Drainage area, 5,200 square miles).

1895.			
July	659	14	149
August	170	16	81
September	19	16	17
October	18	16	17
November	18	17	17
December	18	17	17

TEXAS RIVERS.

A number of measurements of Texas rivers were made during November, 1894, and December, 1895, these being described in geographic order from east to west.

COLORADO RIVER AT AUSTIN.—On December 17, 1895, a measurement was made by Mr. Cyrus C. Babb from the International and Great Northern Railroad bridge. This is about 3 miles below the Austin dam, across the river, holding back the greater part of the water. A number of large springs supply the river channel with water below this point. The measured discharge was 507 second-feet. At a point about a mile above the railroad bridge on the south side of the river the water from Barton springs flows into the river channel. The discharge as measured on November 13, 1894, was 17 second-feet, and on December 18, 1895, 25 second-feet. The channel of Barton creek above the springs was dry each time when measurements were made. There are 3 well-marked springs, the water being held back at the upper one—the largest of the three—by a dam. The water of the lowest spring is utilized to furnish power for a small mill. Measurements were made below this spring at a short distance above the mouth of the creek.

A number of large springs occur in and adjacent to the river channel near the dam. The water from one of these springs issues at the east end of the foundation of the dam itself and has been conducted away through a 12-inch pipe. It is discharged from the side wall of the power house into the river below the dam. A number of estimates place the discharge of this spring at 2,800,000 gallons a day, equivalent in round numbers to 4.3 second-feet.

San Marcos spring.—A measurement of San Marcos spring was made on November 14, 1894, at a point immediately above the railroad bridge at San Marcos, the flow being, in round numbers, 150 second-feet. The spring is controlled by means of an old milldam, water being held back and utilized for furnishing power to a mill and electric light plant. The second measurement was made by Mr. Cyrus C. Babb on December 19, 1895, early in the morning, after the storage of the previous day above the dam had been drawn down. The gates of the mill were so regulated as to give approximately the average discharge of the springs. The measurement was made in the tailrace 50 feet below the head gates, this being the only available place, as the water is divided a short distance below for irrigation purposes. This point is about 1 mile northwest of the town of San Marcos. During the day the water is used in part by a gristmill and in part held back, being used during the night for the electric light plant, which requires more power. The measured discharge was found to be 89 second-feet. This spring is reported to have an annual rise and fall. During March the volume of water increases, and continues to do so until the middle of May, the total rise being about 18 inches. It maintains this level until September and then gradually falls. Measurements were made during low-water stage. The head at that time on the wheel was 7.5 feet, the summer head being 9 feet. This spring did not rise during 1892, 1893, and 1894, but did during 1895. The river is reported to have been 2 feet higher than during the past three years, the supply having decreased within 6 or 7 years.

Comal river.—The Comal river was measured on December 20, 1895, by Mr. Cyrus C. Babb at the highway bridge one-fourth of a mile from the town of New Braunfels. The current was very swift, the mean velocity being 3.81 feet per second and the maximum velocity 8.73 feet per second. The discharge was 328 second-feet, this being considered the normal flow of the springs. The largest spring is located about 1.5 miles above the point of measurement, smaller springs occurring at intervals along the river. This measurement was made about 200 yards below the lower dam and a mile above the junction with the Guadalupe.

San Antonio and San Pedro springs at San Antonio.—It is a matter of some difficulty to select the best locality for measurements, on account of the irregular distribution of the springs and of the ditches diverting water. The upper San Antonio springs are located about 3 miles north of the city. About one-half mile below this, on San Antonio river, are other springs, most of these being covered by ponded water held back by a dam immediately below the lowest spring. Two ditches, the Alamo on the left or eastern side and the Upper Labor on the opposite side of the river divert water from the pond thus formed. Half a mile below this dam is another, diverting nearly the entire flow of San Antonio river into the canal of the lower pumping works of the city water supply. The river was measured on December 21, 1895, by Mr. Cyrus C. Babb. At the head of this latter canal, where the water passes under an arch bridge and through a concrete conduit, the amount found was 34.3 second-feet. The Upper Labor ditch, which comes out above the upper dam, was measured 50 feet below its head works, the discharge being found to be 4 second-feet. The Alamo ditch was also measured 50 feet below its head and ascertained to be carrying 2 second-feet. The entire discharge of the San Antonio springs was ascertained to be a little less than 42 second-feet.

The San Pedro springs occur in a park about 2 miles westerly from the springs just mentioned. A dam has been constructed across the outlet of these springs and water diverted into the San Pedro ditch. The discharge of the San Pedro river on the day given, December 21, 1895, was 2.8 second-feet. There were in San Pedro ditch 6.5 second-feet, giving a total discharge from San Pedro springs of a little less than 9 second-feet.

Sabinal river.—This stream was measured on December 23, 1895, at a point 1.25 miles west of the town of Sabinal, Tex., at the highway ford, about 200 yards below the railroad bridge. No springs occur at this place, but directly under the railroad bridge is a pool of clear water 15 feet deep. The river is dry above this pool, but a small stream, 0.6 second-feet, was flowing from the lower end of it. Water is pumped from the pool to supply a railroad tank, the estimated amount being at the rate of 8,000 gallons an hour. The water apparently issues from a sand bank in the immediate vicinity. In 1892 and 1893 this pool was 12 feet lower than at the ordinary stage, thus having a greatest depth of only about 3 feet, the ordinary depth as above stated being 15 feet. Below this point the river gradually increased in volume.

Leona river.—The location of the Leona spring, in the southern suburbs of Uvalde, was visited on December 23, 1895, but was found to be dry, and it was stated that there had been no water in it for two or three years. The Leona river, 1.5 miles east of the town of Uvalde, was dry under the railroad bridge; water issues, however, from the sands, beginning immediately below the bridges. At a point 1.5 miles south of the town, at the road crossing, the discharge was found to be 11 second-feet. The Sabinal and Leona are similar streams, in that they have no large springs from which the greater part of the water takes its course, but gradually increase in size from about the locality where the line of the Southern Pacific railroad crosses them, the water apparently seeping from the sands in the bed. At the time visited it was stated that the Leona in the hill country, 15 miles to the westward, was a constant stream throughout the year, but between that point and Uvalde the water disappeared in the sands.

LAS MORAS SPRING.—This spring is located at Fort Clark, near Brackettville, Tex., 10 miles distant from Spofford on the Southern Pacific railway. A measurement of this spring was made on December 24, 1895, at a point 300 yards below the dam in the spring and under the footbridge leading from the village to the military post. The discharge at that time was ascertained to be 21 second-feet. It was stated that usually in April the river rises gradually until in July it is 1 foot higher, falling again through the winter.

SAN FELIPE SPRINGS.—Del Rio river has its source in 4 large springs, the upper one being 2 miles above the railroad bridge, the others being within about 200 yards of the bridge at the town of Del Rio. A measurement of the total discharge was made on December 24, 1895, at a point a short distance below the junction of the 2 streams issuing from the 4 main springs. A ditch is diverted from one of these springs above this point, this being ascertained to carry 19 second-feet. The total discharge of the stream below the ditch at a point 1.5 miles east of town and 200 yards below the railroad bridge was ascertained to be 80 second-feet. Adding this to the quantity in the ditch gives a total discharge from the springs of 99 second-feet.

MISCELLANEOUS RIVERS IN TEXAS.

NAME.	Date.	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
Colorado	December 17	1.10	507
Barton springs	December 18	0.68	25
San Marcos	December 19	1.08	89
Comal	December 20	3.81	338
San Antonio	December 21		42
San Pedro	December 21		9
Sabinal	December 23		0.6
Leona	December 23		11
Las Moras spring	December 24	0.41	21
Del Rio ditch	December 24	0.79	19
San Felipe spring	December 24	2.00	80

LIST OF DISCHARGE MEASUREMENTS OF VARIOUS STREAMS IN THE UNITED STATES.

The following list gives in brief the results of individual stream measurements made at various stations established by the United States Geological Survey, and at other points where it has been ascertained that such work has been carried on. For convenience of reference these are arranged in chronologic order. In nearly all instances these measurements were made by means of meters, by which the velocity of various portions of the current was ascertained, the meter being placed at regular intervals across the stream and near the surface, bottom, and in intermediate positions. The depth of the stream having been ascertained by sounding line or pole, and the width measured directly, the discharge for each portion was computed and the results were summed up as shown in the table. This list gives the name of the stream, the locality or river station at which the measurements were made, and the name of the hydrographer or engineer under whose immediate direction the work was done. There is also given, wherever it can be obtained, an estimate of the drainage area in square miles above the point where these measurements were made. This estimate has in general been prepared by means of planimeter measurements of the best accessible maps, the outline of the drainage area being sketched according to the topographic features. Next to the right of this is given the height of water at the time of the measurement on the arbitrary gauge established at the regular river stations; also the mean velocity, obtained by dividing the total computed discharge of the area by the cross section of the river at the point where the measurements were made. The discharge is given in units of cubic feet per second (now commonly employed), briefly designated, for convenience, second-feet.

LIST OF DISCHARGE MEASUREMENTS OF VARIOUS STREAMS IN THE UNITED STATES.

DATE.	Stream.	Locality.	Hydrographer.	Area drained. (Square miles.)	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1893.							
January 14	Umatilla	Pendleton, Ore	W. P. Trowbridge, Jr.	640	1.54		229
June 10	Shell creek	Sheridan road, Wyoming	E. Mead				1
June 10	Clear creek	Above Buffalo, Wyo	do				304
June 12	do	do	do				692
June 14	Piney creek	Sheridan road, Wyoming	do				975
June 14	Fullerton creek	do	do				0
June 14	Rock creek	Road crossing, Wyoming	do				67
June 16	Clear creek	Above Buffalo, Wyo	do				178
June 22	do	do	do			4.494	134
July 6	Bear Gulch creek	Above Kearney, Wyo	M. C. McFarlane				2
July 17	Clear creek	Above Buffalo, Wyo	E. Mead			2.32	37
July 18	Powder river	Old stage crossing	M. C. McFarlane				66
July 24	Sundance creek	Near Sundance, Wyo	E. Mead				1
July 26	Sand creek	Near Beulah, Wyo	do				56
August 14	Yakima	Union gap, Washington	F. H. Newell	3,300	0.90	3.09	2,963
August 14	Naches	North Yakima, Wash	do		1.00	3.70	1,193
August 16	Kahchess lake	Outlet, Washington	do			2.58	211
August 22	West Gallatin	Above Salesville, Mont	do	850	2.15	3.35	818
August 23	Madison	Near Redbluff, Mont	do	2,085	2.10	3.28	1,180
August 24	Jefferson	Threeforks, Mont	do	9,480		1.83	808
August 24	Madison	do	do	2,285	0.30	2.15	1,251
August 25	Missouri	Townsend, Mont	do	15,000	88.75	2.22	3,008
September 2	Bear	Collinston, Utah	do	6,000	1.70	1.40	715
September 10	St. Charles	Below Beulah, Colo	do				4
September 22	Arkansas	Canyon city, Colo	do	3,060	2.45	2.26	291
September 26	Yakima	Union Gap, below Yakima, Wash	S. Storrow		0.25		1,186
September 27	Arkansas	Lajunta, Colo	F. H. Newell	12,200	0.45	1.34	24
September 27	do	Holly, Colo	do	23,500		0	0
1894.							
January 10	Tejon House creek	Kern county, Cal	J. B. Lippincott	17			60
January 21	do	do	do	17			60
March 4	do	do	do	17			86
April 24	Arkansas	Pueblo, Colo	P. J. Preston	4,600		1.95	333
May 8	North Platte	Orin junction, Wyoming	E. Mead	14,828			6,633
May 15	Arkansas	Canyon, Colorado	F. H. Newell	3,060	4.20	7.27	2,395
May 18	South Side ditch	do	do			1.88	22
May 18	North Side ditch	do	do			2.45	27
May 18	Arkansas	do	do	3,060	3.80	6.08	1,940
May 21	Little Laramie	South Fork, Wyoming	Luke Voorhees			3.57	69
May 21	Henry canal	Lajunta, Colo	F. H. Newell			3.08	620
May 21	Arkansas	do	do	12,200	1.20	1.57	157
May 21	Otero canal	do	do			1.00	5
May 24	Potomac	Cumberland, Md	C. C. Babb	891		2.60	3,637
May 28	Rockyford ditch	Rockyford, Colo	F. H. Newell			2.23	71
May 28	Laguna ditch	do	do			2.83	187
May 28	Catlin ditch	do	do			2.41	104
May 28	Otero	do	do			1.70	138
May 28	High Line canal	do	do			2.12	115
May 29	Vroomans	do	do			1.25	10
May 29	Rockyford ditch	Rockyford, Colo	F. H. Newell			2.68	110
May 29	Otero ditch	Apishapa flume, Colorado	do			1.66	141
May 29	Catlin ditch	Near head, Colorado	do			2.76	290
May 29	Oxford ditch	do	do			4.83	174
May 29	High Line	do	do			2.87	265
May 31	Potomac	Springfield, W. Va	R. H. Chapman	1,443	4.70	2.02	1,074
June 1	Fosdicks ditch	Near head, Colorado	F. H. Newell			2.06	70
June 1	Arkansas	Nepesta, Colo	do			4.00	12,000
June 2	do	do	do			3.90	8,000
June 6	Laramie river	Uva bridge, Wyoming	E. Mead	3,179			1,845
June 7	Arkansas	Lajunta, Colo	F. H. Newell	12,200	7.80	3.33	15,000
June 7	North Platte	Orin junction, Wyoming	E. Mead	14,828			12,823
June 8	Arkansas	Lajunta, Colo	F. H. Newell	12,200	6.40	3.06	9,500
June 13	Rio Grande	Del Norte, Colo	do	1,400	2.68		968
June 14	Little Goose creek	Sheridan county, Wyo	M. C. McFarlane				165
June 14	Wolf creek	Canyon bridge, Wyoming	do				63
June 18	Arkansas	Canyon, Colorado	F. H. Newell	3,060	4.50		2,387
June 20	Big Goose creek	Sheridan, Wyo	M. C. McFarlane				463
June 24	Tejon House creek	Kern county, Cal	J. B. Lippincott	17			7
June 25	Shell creek	Shell, Wyo	E. Mead			5.21	569
June 26	Big Horn	Lovells ferry, Wyoming	do				26,010
July 2	Stinking Water	Marquette, Wyo	do				4,623
July 2	Potomac	Harpers Ferry, W. Va	C. C. Babb	6,354	2.32	1.20	1,223
July 6	Shenandoah	do	do	3,009		2.61	1,218
July 12	Gray Bull	Meeteetse, Wyo	E. Mead				1,299
July 15	Wind	Merritts, Wyoming	do			7.35	6,209
July 17	Big Popo Agie	25 miles below Lander, Wyo	M. C. McFarlane				624
July 18	Little Popo Agie	Below Youngs, Wyoming	do				91
July 20	Big Sandy	Lander Cut-of trail, Wyoming	do			2.30	148
July 20	Weber	Uinta, Utah	S. Fortier	1,600	1.10	2.84	396
July 21	New Fork	4 miles aboveforks, Wyoming	M. C. McFarlane				2,055
July 21	Green	Above Newfork, Wyo	do				2,427
July 21	Potomac	Chain bridge, District of Columbia	C. C. Babb	11,161	13.47	0.80	1,781
July 23	North Piney creek	Uinta county, Wyo	M. C. McFarlane				295
July 23	Middle Piney	North branch, Wyoming	do				256
July 23	do	Uinta county, Wyo	do				93

LIST OF DISCHARGE MEASUREMENTS OF VARIOUS STREAMS IN THE UNITED STATES—Continued.

DATE.	Stream.	Locality.	Hydrographer.	Area drained. (Square miles.)	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1894.							
July 23	Middle Piney	In canyon, Wyoming	M. C. McFarlane				140
July 26	North Platte	Camp Clarke, Neb	O. V. P. Stout				1,900
July 26	Pumpkinseed creek	Cary, Cheyenne county, Neb	do				17
July 28	North Platte	Gering, Neb	do				2,450
July 30	Strawberry creek	In canyon, Wyoming	M. C. McFarlane			6.85	195
July 31	Loup	Columbus, Neb	O. V. P. Stout	13,542			1,475
August 4	Salt	In pass, Wyoming	M. C. McFarlane				628
August 4	Willow creek	Near mouth, Wyoming	do				104
August 7	Frenchman	Palisade, Neb	O. V. P. Stout				94
August 7	Republican	Culbertson, Neb	do			0	0
August 10	Swift creek	Afton bridge, Wyoming	M. C. McFarlane				155
August 13	Stump creek	Above Auburn, Wyo	do				67
August 14	Platte	Fremont, Neb	O. V. P. Stout				1,420
August 15	Elkhorn	Waterloo, Neb	do				280
August 15	North Platte	Orin junction, Wyoming	W. M. Gilcrest	14,828			516
August 15	Weber	Uinta, Utah	S. Fortier	1,600	0.50	1.73	141
August 17	Crow creek	At bridge, Wyoming	M. C. McFarlane				77
August 19	Loup	S. 13, T. 7 N., R. 2 W., Nebraska	L. F. Gottschalk				1,335
August 20	Laramie	Near Laramie, Wyo	John Hunton	3,179		1.38	51
August 21	Dry creek	Near Afton, Wyo	M. C. McFarlane				56
August 22	Dismal	Near Dunning, Neb	G. H. Lawrence				435
August 25	Middle Loup	Gates, Neb	do				850
August 25	Cottonwood creek	South of Afton, Wyo	M. C. McFarlane				79
August —	Platte	Fremont, Neb	A. Rosewater				1,209
August —	Elkhorn	Arlington, Neb	do				214
September 5	Trejon House creek	Kern county, Cal	J. B. Lippincott	17			1
September 10	South Loup	Georgetown, Neb	G. H. Lawrence				68
September 15	Cedar	Fullerton, Neb	O. V. P. Stout				210
September 16	Loup	do	do				1,704
September 17	Beaver creek	Genoa, Neb	do				71
September 17	Platte	Columbus, Neb	do	56,867		0	0
September 19	Arkansas	Pueblo, Colo	A. P. Davis	4,600	0.35	2.50	378
September 20	do	Canyon city, Colo	do	3,060	2.65	2.81	395
September 20	South Side ditch	do	do				33
September 20	North Side ditch	do	do				22
September 23	Lake creek	Twinlakes, Colo	do	102		1.00	43
September 24	Arkansas	Hayden, Colo	do		1.20	1.93	114
September 27	Rio Grande	Del Norte, Colo	do	1,400	1.52	2.34	267
September 27	Laramie	Laramie, Wyo	W. M. Gilcrest				27
September 28	Rio Grande	Alamosa, Colo	A. P. Davis			1.01	11
September 28	Laramie	Woods landing, Wyoming	W. M. Gilcrest	435			57
September 30	Rio Grande	Embudo, N. Mex	A. P. Davis	7,000	7.70	1.50	284
October 1	do	do	do	7,000		3.25	1,138
October 3	North Platte	Uva junction, Wyoming	F. H. Newell				
October 4	Mora	Watrous, N. Mex	A. P. Davis		1.68	1.05	35
October 5	North Platte	North Platte, Neb	Chas. P. Ross	28,517		1.58	630
October 5	Arkansas	Lajunta, Colo	A. P. Davis	12,200	0.40		55
October 6	Bear	Collinston, Utah	S. Fortier	6,600	2.01	2.61	1,800
October 6	Platte	Columbus, Neb	O. V. P. Stout	56,867		0	0
October 7	Laramie	Near Fort Laramie	John Hunton	3,179		1.89	23
October 11	North Platte	Ogallala, Neb	F. H. Newell				609
October 13	Arkansas	Pueblo, Colo	A. P. Davis	4,600	0.39	2.36	370
October 15	do	Canyon city, Colo	do	3,060	2.40		319
October 15	South Side ditch	do	do				33
October 15	North Side ditch	do	do				27
October 16	Arkansas	Hayden, Colo	do		1.24	2.00	91
October 17	Gunnison	Grand Junction, Colo	do	7,935	1.25	0.80	748
October 18	Grand	do	do	8,644	2.10	1.10	1,585
October 21	Green	Blake, Utah	do		1.98	1.83	3,035
October 22	Pine	Helper, Utah	do		2.65		34
October 24	Humboldt	Golconda, Nev	L. H. Taylor	10,780	1.30	1.29	57
October 24	Provo	Provo, Utah	A. P. Davis	640	4.38		338
October 24	Laramie	Uva, Wyo	W. M. Gilcrest	3,179		2.06	14
October 26	North Platte	Orin junction, Wyoming	do	14,828		1.42	502
October 27	Red river	Fargo, N. Dak	F. H. Newell				190
October 29	Bear	Battle Creek, Utah	A. P. Davis	4,500	1.90	2.12	980
October 30	St. Louis	Cloquet, Minn	F. H. Newell				6,067
November 1	Snake	Blackfoot, Idaho	A. P. Davis	10,500		1.90	8,040
November 2	North Loup	Moulton, Neb	G. H. Lawrence				460
November 3	Laramie	Woods landing, Wyoming	W. M. Gilcrest	435		1.47	80
November 4	Madison	Threeforks, Mont	A. P. Davis	2,283	0.57	1.00	1,404
November 6	North Platte	North Platte, Neb	Chas. P. Ross	28,517		1.72	1,227
November 7	do	Near Fort Laramie, Wyo	John Hunter	16,416		2.23	630
November 13	Barton spring	Austin, Tex	F. H. Newell				17
November 14	San Marcos	San Marcos, Tex	do				150
November 14	Jefferson	Sappington, Mont	A. P. Davis	8,270	1.08	2.67	1,952
November 17	Gallatin	Logan, Mont	do		1.11	1.82	772
November 18	Missouri	Townsend, Mont	do	15,000	89.00	2.44	3,766
November 21	Naches	Nelson bridge, Washington	do		2.50	2.44	1,196
November 24	Toppenish	Railroad crossing, Washington	do		3.40	2.40	49
November 24	Satas	North Branch, Washington	do		2.00	3.00	27
November 25	Yakima	Union gap, Washington	do	3,300		5.74	3,026
November 30	Bear	Battle Creek, Utah	S. Fortier	4,500	1.80	2.14	957
November 30	do	do	do	4,500	1.80	4.48	1,030
December 4	Humboldt	Golconda, Nev	L. H. Taylor	10,780	2.00	1.31	114

LIST OF DISCHARGE MEASUREMENTS OF VARIOUS STREAMS IN THE UNITED STATES—Continued.

Date.	Stream.	Locality.	Hydrographer.	Area drained. (Square miles.)	Gauge height. (Feet).	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1894.							
December 6	Weiser	Weiser canyon, Idaho	A. P. Davis	1,670	1.80	1.10	277
December 7	Payette	Payette, Idaho	do		1.30	2.56	1,603
December 8	Frenchman	Palisade, Neb	O. V. P. Stout		1.87	1.41	116
December 8	Owyhee	County bridge, Oregon	A. P. Davis	9,875	1.40	1.47	307
December 9	Republican	Benkelman, Neb	O. V. P. Stout		1.74	2.31	75
December 10	Malheur	Vale, Ore	A. P. Davis	9,900	1.90	2.00	128
December 20	Sacramento	Redbluff, Cal	do	9,356	10.70	8.60	[a]45,000
December 22	Bear	Collinston, Utah	S. Fortier	6,000	2.10	2.57	957
December 24	Provo	Provo, Utah	do	640	4.46	2.53	390
1895.							
January 6	Mokelumne	Lodi, Cal	A. P. Davis		12.25	1.04	1,063
January 8	Tuolumne	Modesto, Cal	do	1,635	7.70	2.01	3,003
January 9	San Joaquin	Herndon, Cal	do	1,637	4.00	1.67	1,995
January 10	Kings	Kingsburg, Cal	do	1,742	6.00	0.92	1,830
January 16	Whitewater	Whitewater, Cal	do			8.40	4,800
January 17	Colorado	Yuma, Ariz	do	225,049	19.66	3.80	9,737
January 23	Potomac	Chain Bridge, D. C	C. C. Babb	11,161	17.10		20,028
January 25	Rio Grande	El Paso, Tex	A. P. Davis	30,000	2.65	0.87	230
January 28	Weber	Uinta, Utah	J. L. Rhead	1,600	0.85	1.31	166
January 29	Rio Grande	San Marcial, N. Mex	A. P. Davis		6.40	0.38	89
February 1	do	Watertank, New Mexico	P. E. Harroun		4.60	3.11	652
February 2	do	Embudo, N. Mex	A. P. Davis	7,000	7.98	2.23	464
February 4	do	do	do	7,000	8.01	2.25	453
February 6	Arkansas	Lajunta, Colo	do	12,200	1.95	1.90	182
February 6	do	Pueblo, Colo	do	4,600	0.40	2.75	411
March 6	Tejon House creek	Tejon Ranch house, California	J. B. Lippincott	17			23
March 19	Sacramento	Redbluff, Cal	do	9,356	4.80		15,461
March 20	Mokelumne	Lodi, Cal	do		8.00		1,068
March 21	Tuolumne	Modesto, Cal	do	1,635	6.90	1.76	2,429
March 23	San Joaquin	Herndon, Cal	do	1,637	3.65		1,938.
March 22	Frenchman	Culbertson, Neb	O. V. P. Stout				130
March 22	Frenchman	Palisade, Neb	do		1.52	1.88	100
March 22	Humboldt	Golconda, Nev	L. H. Taylor	10,780	3.82	2.12	463
March 23	King	Kingsburg, Cal	J. B. Lippincott	1,742	4.10	0.39	500
March 23	South Fork Republican	Benkelman, Neb	O. V. P. Stout		1.89	1.70	41
March 23	North Fork Republican	do	do		1.89	2.01	72
March 25	Potomac	Point of Rocks, Md	C. C. Babb	9,654	3.45	1.68	10,524
March 27	North Platte	North Platte, Neb	C. P. Ross	28,517	2.20	1.88	2,329
March 29	South Branch of Potomac	Bridge near Springfield, W. Va	C. C. Babb	1,443	1.25	2.95	2,049
March 29	Loup	Columbus, Neb	O. V. P. Stout	13,542	1.77	3.75	2,790
March 29	Platte	do	do	50,867	0.40		2,531
March 30	Potomac	Cumberland, Md	C. C. Babb	891	4.50	3.17	3,446
April 3	Tejon House creek	Tejon Ranch house, California	J. B. Lippincott	17		3.40	17
April 3	Caliente	Caliente, Cal	do	219		2.30	23
April 5	Potomac	Point of Rocks, Md	C. C. Babb	9,654	3.82	2.21	14,032
April 6	Bear	Battle Creek, Idaho	J. L. Rhead	4,500	2.68	3.38	2,092
April 8	Rio Grande	Embudo, N. Mex	P. E. Harroun	7,000	9.40	2.94	1,175
April 8	Bear	Collinston, Utah	S. Fortier	6,000	3.16	3.01	3,041
April 10	Potomac	Cumberland, Md	C. C. Babb	891	5.40	3.88	6,054
April 11	South branch	Bridge near Springfield, W. Va	do	1,443	8.95	2.95	4,389
April 12	Blue	Manhattan, Kan	A. P. Davis	9,490	3.60	1.48	542
April 13	Potomac	Point of Rocks, Md	C. C. Babb	9,654	4.67	2.23	17,516
April 15	Bear	Battle Creek, Idaho	J. L. Rhead	4,500	3.00	3.57	2,380
April 15	Bear	Collinston, Utah	S. Fortier	6,000	3.75	3.44	3,853
April 16	Smoky Hill	Ellsworth, Kan	W. G. Russell	7,980	1.50	0.84	12
April 18	Colorado	Yuma, Ariz	J. B. Lippincott	225,049	20.25	5.23	21,095
April 18	Saline	Beverly, Kan	A. P. Davis	2,730	1.50	1.35	22
April 19	Rio Grande	Watertank, N. Mex	P. E. Harroun		9.80	6.55	5,174
April 20	Boise	At mouth of Boise canyon, Idaho	V. C. Tompkins		5.00	3.42	4,770
April 20	Solomon	Beloit, Kan	A. P. Davis	5,539	2.90	1.60	148
April 21	Loup	Columbus, Neb	O. V. P. Stout	13,542	4.65	3.41	2,303
April 22	Rio Grande	San Marcial, N. Mex	P. E. Harroun		9.50	6.07	7,805
April 22	Bear	Collinston, Utah	S. Fortier	6,000	3.58	3.27	3,453
April 23	Potomac	Point of Rocks, Md	C. C. Babb	9,654	2.50	1.55	7,371
April 24	Shenandoah	Millville, W. Va	do	2,995	1.90	1.18	2,163
April 24	Arkansas	Pueblo, Colo	Porter J. Preston	4,600	4.60	1.95	322
April 24	Weiser	Weiser canyon, Idaho	V. C. Tompkins	1,670	3.40	2.90	2,110
April 25	Potomac	Cumberland, Md	C. C. Babb	891	3.30	1.49	630
April 26	Malheur	Vale, Ore	V. C. Tompkins	9,900	3.00	0.74	521
April 26	South Branch	Bridge near Springfield, W. Va	C. C. Babb	1,443	4.20	2.45	968
April 27	Republican	Junction city, Kan	E. C. Murphy	25,837	3.00	1.52	219
April 27	Smoky Hill	do	A. P. Davis	20,428		0.33	188
April 27	Sacramento	Redbluff, Cal	J. B. Lippincott	9,356	8.40	7.72	36,181
April 28	Gallatin	Logan, Mont	A. M. Ryon		2.00	2.74	1,461
April 29	Bear	Battle Creek, Idaho	J. L. Rhead	4,500	2.93	3.50	2,268
April 29	do	Collinston, Utah	S. Fortier	6,000	3.61	3.27	3,460
April 29	North Platte	North Platte, Neb	C. P. Ross	28,517	2.90	2.16	5,695
April 30	Sacramento	Jellys Ferry, Cal	J. B. Lippincott	9,356	12.00	5.96	23,457
April 30	Salt creek	Lincoln, Neb	O. V. P. Stout				1,500
May 1	Potomac	Point of Rocks, Md	C. C. Babb	9,654	4.75	2.73	21,073
May 1	Tuolumne	Modesto, Cal	J. B. Lippincott	1,635	10.25	2.55	6,078
May 1	Shenandoah	Millville, W. Va	C. C. Babb	2,995	7.50	4.07	19,711
May 2	Tuolumne	Modesto, Cal	J. B. Lippincott	1,635	12.90		13,546
May 2	Shenandoah	Millville, W. Va	C. C. Babb	2,995	6.80	3.61	15,859
May 3	South Branch	Bridge near Springfield, W. Va	do	1,443	7.40	3.62	3,539

[a] Approximate.

LIST OF DISCHARGE MEASUREMENTS OF VARIOUS STREAMS IN THE UNITED STATES—Continued.

DATE.	Stream.	Locality.	Hydrographer.	Area drained. (Square miles.)	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.							
May 3	Stanislaus	Oakdale, Cal	J. B. Lippincott	1,051	8.80	3.92	7,744
May 3	Potomac	Cumberland, Md	C. C. Babb	891	3.75	2.39	1,728
May 3	Platte	Columbus, Neb	O. V. P. Stout	56,867		2.56	5,550
May 4	Shenandoah	Millville, W. Va.	C. C. Babb	2,995	5.20	3.17	10,981
May 4	North Loup	St. Paul, Neb	O. V. P. Stout	4,024	3.27	2.64	1,530
May 5	....do	Ord, Neb	....do			2.28	1,367
May 5	San Joaquin	Herndon, Cal	J. B. Lippincott	1,637	6.65		7,419
May 6	Medicine	Kiowa, Kan	A. P. Davis		2.35	0.91	22
May 7	South Platte	Denver, Colo	P. J. Preston	3,840	1.10	1.48	168
May 7	Potomac	Point of Rocks, Md	C. C. Babb	9,654	3.50	2.16	12,484
May 8	Shenandoah	Millville, W. Va.	....do	2,995	3.08	1.80	4,311
May 9	Cimarron	Below Bluff Creek, Kan	A. P. Davis			0.18	1
May 9	South Branch	Bridge near Springfield, W. Va.	C. C. Babb	1,443	5.25	3.30	1,588
May 9	Big Thompson	Home Supply dam, Colorado	P. J. Preston		1.25	2.17	260
May 9	Potomac	Cumberland, Md	C. C. Babb	891	3.40	1.67	777
May 10	Perrys ditch	Near Englewood, Kan	A. P. Davis			1.25	14
May 10	Cimarron	....do	....do				23
May 11	Rio Grande	Rio Grande, N. Mex	P. E. Harroun		8.00	5.86	4,249
May 11	St. Vrain	Lyons, Colo	P. J. Preston		1.65	3.33	200
May 11	Boise	At mouth of Boise canyon, Idaho	V. C. Tompkins		5.30	3.76	5,562
May 11	Gallatin	Logan, Mont	P. Seih		2.60	3.37	2,113
May 12	Madison	Threeforks, Mont	....do		0.80	3.28	3,114
May 13	Arkansas	Hutchinson, Kan	A. P. Davis		1.30	0.90	10
May 14	South Boulder creek	Marshall, Colo	P. J. Preston	125	2.00	3.09	164
May 14	Cimarron	Below Bluff Creek, Kan	A. P. Davis		2.50	1.31	17
May 14	Rio Grande	Embudo, N. Mex	P. E. Harroun	7,000	11.12	4.39	3,219
May 16	White	White River city, Colo	H. A. Sumner	1,773	13.10	5.81	3,047
May 17	Potomac	Point of Rocks, Md	C. C. Babb	9,654	2.75	1.74	8,918
May 18	Bear creek	Morrison, Colo	P. J. Preston	170	0.90	2.17	47
May 18	Moro	Watrous, N. Mex	A. P. Davis		1.50	0.89	18
May 19	Rio Grande	San Marcial, N. Mex	P. E. Harroun		7.60	5.49	3,458
May 19	Arkansas	Lajunta, Colo	A. P. Davis	12,200	1.90	2.22	658
May 20	....do	Pueblo, Colo	....do	4,600	1.65	4.78	1,435
May 22	Platte	Columbus, Neb	O. V. P. Stout	56,867		2.61	5,896
May 22	South Branch	Bridge near Springfield, W. Va.	C. C. Babb	1,443	8.30	3.16	3,888
May 23	Potomac	Cumberland, Md	....do	891	3.40	1.46	831
May 24	Shenandoah	Millville, W. Va	....do	2,905	3.60	1.76	5,745
May 24	Laramie	Woods landing, Wyoming	W. M. Gilcrest	435	2.80	4.74	1,129
May 24	Malheur	Vale, Ore	V. C. Tompkins	9,900	2.10	0.70	261
May 25	Owyhee	Owyhee, Ore	....do	9,875	2.40	1.12	773
May 28	Weiser	Weiser canyon, Idaho	....do	1,670	4.95	2.55	2,149
May 28	Potomac	Point of Rocks, Md	C. C. Babb	9,654	2.85	1.74	9,189
May 28	North Platte	North Platte, Neb	C. P. Ross	28,517	2.90	2.43	6,320
May 31	Arkansas	Canon City, Colo	A. P. Davis	3,060	4.35	7.10	2,434
June 1	Rio Grande	San Marcial N. Mex	P. E. Harroun		8.60	4.12	4,714
June 3	Republican	Oxford, Neb	O. V. P. Stout			7.67	16,000
June 3	Arkansas	Swallows, Colo	A. P. Davis	4,300		5.30	2,261
June 3	Potomac	Point of Rocks, Md	C. C. Babb	9,654	1.93	1.13	4,536
June 4	North Fork Republican	Morse's ranch, Nebraska	O. V. P. Stout		1.68	2.83	141
June 4	South Fork Republican	Benkelman, Neb	....do		5.55	2.90	348
June 4	Arkansas	Bridge No. 3, Colorado	A. P. Davis	4,600		3.18	1,973
June 4	....do	Bridge No. 155 B, Colorado	....do	4,600		5.46	2,022
June 4	South Branch	Bridge near Springfield, W. Va.	C. C. Babb	1,443	3.90	2.15	710
June 5	Frenchman	Palisade, Neb	O. V. P. Stout		1.76	1.55	154
June 5	Smoky Hill	Ellsworth, Kan	W. G. Russell	7,980	9.05	2.91	5,402
June 5	Rio Grande	Watertank New Mexico	P. E. Harroun		9.10	5.86	6,689
June 5	Potomac	Cumberland, Md	C. C. Babb	891	2.95	1.16	216
June 6	South Branch	Bridge near Springfield, W. Va.	....do	1,443	3.90	2,13	759
June 6	Potomac	Cumberland, Md.	....do	891	3.10	1.76	530
June 8	Shenandoah	Millville, W. Va	....do	2,995	1.50	0.92	1,516
June 8	North Platte	North Platte, Neb	C. P. Ross	28,517	4.00	2.85	16,261
June 8	Saline	Beverly, Kan	W. G. Russell	2,730	9.90	2.77	1,238
June 11	Arkansas	Pueblo, Colo	A. P. Davis	4,600	2.80	6.89	2,758
June 11	Platte	Columbus, Neb	O. V. P. Stout	56,867	2.28		27,214
June 12	Bear creek	Morrison, Colo	P. J. Preston	170	2.05	4.77	331
June 12	Loup	Columbus, Neb	O. V. P. Stout	13,542	4.55	3.39	2,836
June 13	Arkansas	Canyon city, Colo	A. P. Davis	3,060	4.50	6.73	2,397
June 13	Potomac	Cumberland, Md	C. C. Babb	891	3.00	0.83	149
June 13	Ogden	Near Ogden, Utah	J. L. Rhead	360	2.02	1.43	150
June 14	North Platte	Gering, Neb				2.85	11,350
June 14	Rio Grande	Del Norte, Colo	F. Cogswell	1,400	4.00	5.88	2,818
June 14	South Branch	Bridge near Springfield, W. Va	C. C. Babb	1,443	3.47	2.27	586
June 14	North Platte	Gering, Neb	O. V. P. Stout			2.77	9,908
June 14	Laramie	Uva, Wyo	W. M. Gilcrest	3,179	4.75	4.04	1,417
June 15	Shenandoah	Millville, W. Va	C. C. Babb	2,995	2.35	1.42	3,044
June 15	Provo	Provo canyon, Utah	J. L. Rhead	640	4.80	3.60	680
June 16	Rio Grande	Alamosa, Colo	F. Cogswell		5.18	2.08	1,176
June 17	North Platte	Gering, Neb	O. V. P. Stout				10,962
June 17	Humboldt	Elko, Neb	L. H. Taylor	2,840	1.50	2.50	186
June 17	North Platte	Gering, Neb	O. V. P. Stout			3.27	10,963
June 17	Weber	Devils Gate, above Uinta, Utah	J. L. Rhead	1,600	2.20	4.04	955
June 17	Potomac	Point of Rocks, Md	C. C. Babb	9,654	1.70	1.12	4,233
June 18	Rio Las Animas	Durango, Colo	F. Cogswell	812	6.50	3.55	1,893
June 18	....do	....do	....do		6.50	3.55	1,898
June 19	South Branch	Bridge near Springfield, W. Va	C. C. Babb	1,443	3.10	1.79	249

LIST OF DISCHARGE MEASUREMENTS OF VARIOUS STREAMS IN THE UNITED STATES—Continued.

Date.	Stream.	Locality.	Hydrographer.	Area drained. (Square miles.)	Gauge height. (Feet.)	Mean velocity. (Feet per second.	Discharge. (Second-feet.)
1895.							
June 20	Potomac	Dam No. 6, Md	C. C. Babb	4,059	0.90		331
June 20	Arkansas	Hutchinson, Kan	W. G. Russell		3.40	1.98	1,471
June 20	Green	Green River city, Wyo	W. M. Gilcrest		3.30	3.43	3,886
June 21	Humboldt	Golconda, Nev	L. H. Taylor	10,780	2.55	1.35	204
June 21	Medicine	Kiowa, Kan	W. G. Russell		2.40	1.34	66
June 21	Chama	Abiquiu, N. Mex	P. E. Harroun	2,300	2.50	1.50	404
June 21	San Juan	Arboles, Colo	F. Cogswell	1,394	7.30	3.50	1,556
June 21	Piedra	do	do	650	3.90	3.40	606
June 22	Dolores	Dolores, Colo	do	562	3.50	3.40	756
June 22	Shenandoah	Millville, W. Va	C. C. Babb	2,995	1.10	0.77	1,126
June 22	Walker	Nordyke, Nev	L. H. Taylor	812	2.30	2.74	817
June 23	San Joaquin	Herndon, Cal	J. B. Lippincott	1,637	8.00	3.98	11,225
June 24	Cimarron	Arkalon, Kan	W. G. Russell		2.70	1.30	16
June 24	South Fork Republican	Benkelman, Neb	O. V. P. Stout		1.50	1.79	75
June 24	North Fork Republican	do	do		1.06	1.45	36
June 24	Boise	Boise Canyon, Idaho	V. C. Tompkins		4.60	2.71	4,115
June 24	San Miguel	Seymour, Colo	F. Cogswell	327	4.00	4.90	512
June 25	Carson	Near Empire, Brunswick dam, Nevada	L. H. Taylor	894	4.10		1,855
June 25	Platte	Columbus, Neb	O. V. P. Stout	56,867	1.42		12,481
June 25	Uncompahgre	Uncompahgre, Colo	F. Cogswell	497	4.60	6.80	834
June 25	Kings	Suspension bridge, California	J. B. Lippincott		13.20	5.38	10,300
June 26	Weiser	Weiser canyon, Idaho	V. C. Tompkins	1,670	2.30	1.28	409
June 26	Gallatin	Logan, Mont	P. Seih		3.40	4.17	3,289
June 27	Walker	Nordyke, Nev	L. H. Taylor		2.95	3.84	2,228
June 27	North Platte	Orin Junction, Wyoming	W. M. Gilcrest	14,828	3.80	4.29	4,110
June 27	Tuolumne	Modesto, Cal	J. B. Lippincott	1,635	3.00	3.01	9,308
June 27	Madison	Threeforks, Mont	P. Seih		1.00	3.59	3,287
June 27	Grand	Grand Junction, Colo	A. P. Davis	8,644	4.03	5.77	16,500
June 28	North Loup	St. Paul, Neb	O. V. P. Stout	4,024	3.21	2.26	1,127
June 28	Middle Loup	do	do	6,849	1.83	1.93	1,046
June 28	Payette	Payette, Idaho	V. C. Tompkins		3.50	2.35	3,723
June 28	Gunnison	Grand Junction, Colo	A. P. Davis	7,935	4.74	2.94	4,178
June 29	Missouri	Townsend, Mont	P. Seih	15,000	91.05	4.67	10,699
June 29	Malheur	Vale, Ore	V. C. Tompkins	9,900	0.80	0.63	28
June 29	Loup	Columbus, Neb	O. V. P. Stout	13,542	4.50	3.27	2,715
June 30	Owyhee	Owyhee, Ore	V. C. Tompkins	9,875	1.30	0.80	213
June 30	Green	Blake, Utah	A. P. Davis		5.80	4.43	15,065
June 30	Sacramento	Jellys Ferry, Cal	J. B. Lippincott	9,356	2.70	3.25	8,456
July 1	Price	Helper, Utah	A. P. Davis		1.00	1.80	119
July 2	Green	Green River city, Wyo	W. M. Gilcrest		4.25	3.97	7,011
July 2	Stanislaus	Oakdale, Cal	J. B. Lippincott	1,051	6.15	2.98	3,754
July 3	Arkansas	Granite, Colo	A. P. Davis	425	0.50	5.49	1,065
July 3	South Fork Republican	Benkelman, Neb	O. V. P. Stout		2.60	2.48	278
July 3	Truckee	Tahoe city, Cal	L. H. Taylor		3.90	9.63	1,197
July 3	Smoky Hill	Ellsworth, Kan	W. G. Russell	7,980	2.60	1.69	217
July 4	Frenchman	Palisade, Neb	O. V. P. Stout		1.61	1.50	74
July 10	Colorado	Yuma, Ariz	J. B. Lippincott	225,049	21.20	5.46	45,533
July 10	Potomac	Point of Rocks, Md	C. C. Babb	9,654	1.90	1.14	4,695
July 11	Blue	Manhattan, Kan	O. P. Hood	9,490	3.70	1.38	420
July 12	Humboldt	Golconda, Nev	L. H. Taylor	10,780	1.62	1.15	96
July 12	Shenandoah	Millville, W. Va	C. C. Babb	2,995	1.30	0.74	1,150
July 13	Humboldt	Elko, Nev	L. H. Taylor	2,840	0.80	1.14	48
July 15	Laramie	Uva, Wyo	W. M. Gilcrest	3,179	1.60	1.65	146
July 15	Mora	Watrous, N. Mex	P. E. Harroun		2.00	0.85	131
July 15	Platte	Columbus, Neb	O. V. P. Stout	56,867	0.72		5,338
July 16	Rio Grande	San Marcial, N. Mex	P. E. Harroun		6.60	2.38	1,503
July 16	South Branch	Bridge near Springfield, W. Va	C. C. Babb	1,443	3.10	1.73	378
July 17	South Branch	Bridge near Springfield, W. Va	do	1,443	3.00	1.82	355
July 17	Boulder creek	Boulder, Colo	P. J. Preston	179	1.90	3.80	317
July 17	North Platte	Orin junction, Wyoming	W. M. Gilcrest	14,828	2.90	3.20	2,475
July 17	Gunnison	Grand Junction, Colo	A. P. Davis	7,935	3.60	1.90	2,642
July 17	Canal feeder	Cumberland, Md	C. C. Babb		3.05		79
July 17	Potomac	do	do	891	3.05	1.33	268
July 18	South Boulder creek	Marshall, Colo	P. J. Preston	125	2.00	3.19	196
July 18	Boise	Boise canyon, Idaho	G. F. Sherman			1.98	1,706
July 18	Potomac	Dam No. 6, Md	C. C. Babb	4,050	0.90		543
July 18	Canal feeder	do	do		0.90		164
July 19	Rio Grande	El Paso, Tex	P. E. Harroun	30,000	8.10	0.71	1,039
July 19	Big Thompson	Home supply dam, Colorado	P. J. Preston		1.90	3.59	490
July 19	Kansas	Lawrence, Kan	E. C. Murphy	59.841	2.70	1.60	8,904
July 20	Owyhee	Owyhee, Ore	G. F. Sherman	9,875	1.00	0.54	64
July 20	Kansas	Lawrence, Kan	E. C. Murphy	59,841	2.75	1.07	3,352
July 20	St. Vrain	Lyons, Colo	P. J. Preston	209	8.40	3.27	326
July 20	Provo	Provo, Utah	A. P. Davis	640	4.10	2.19	277
July 21	Malheur	Vale, Ore	G. F. Sherman	9,900	0.58	0.97	9
July 22	West Gallatin	Williams ranch, Montana	A. M. Ryon		1.61	4.50	1,153
July 22	Payette	Payette, Idaho	G. F. Sherman		1.53	2.29	1,883
July 22	Saline	Beverly, Kan	W. G. Russell	2,730	4.10	1.76	226
July 23	Weiser	Lanes ranch, Idaho	G. F. Sherman		1.70	0.54	121
July 24	Bear creek	Morrison, Colo	P. J. Preston	170	1.65	2.96	171
July 23	Rio Grande	Watertank, New Mexico	P. E. Harroun		6.60	4.41	2,095
July 23	Weber	Devils Gate, Utah	A. P. Davis	1,600	1.20	1.93	222
July 23	Cimarron	Arkalon, Ark	W. G. Russell		7.00	1.79	319
July 23	South Platte	Denver, Colo	F. Cogswell	3,840	5.40	3.63	1,499

LIST OF DISCHARGE MEASUREMENTS OF VARIOUS STREAMS IN THE UNITED STATES—Continued.

Date.	Stream.	Locality.	Hydrographer.	Area drained. (Square miles.)	Gauge height. (Feet.)	Mean velocity. (Feet per second.	Discharge. (Second-feet.)
1895.							
July 23	Walker	Nordyke, Nev	L. H. Taylor		2.30	2.74	817
July 25	Chama	Abiquin, N. Mex	P. E. Harroun	2,300	2.90	1.33	206
July 25	Medicine	Kiowa, Kan	W. G. Russell		3.20	1.70	294
July 25	Kings	Suspension bridge, California	J. B. Lippincott		16.00	4.99	
July 26	Boise	Mouth of canyon, Idaho	A. P. Davis		2.45	2.20	1,552
July 27	Arkansas	Hutchinson, Kan	W. G. Russell		5.65	3.93	12,300
July 27	Rio Grande	Embudo, N. Mex	P. E. Harroun	7,000	9.90	3.88	1,669
July 27	Kansas	Lawrence, Kan	E. C. Murphy	59,841	1.90	1.20	6,411
July 27	Walker	Nordyke, Nev	L. H. Taylor		3.95	3.84	2,228
July 28	Lower Boise	Caldwell, Idaho	A. P. Davis		3.80	4.00	756
July 29	Gallatin	Logan, Mont	A. M. Ryon		0.90	1.37	477
July 29	Weiser	Lanes ranch, Idaho	A. P. Davis		1.58	0.72	141
July 29	Gallatin	Logan, Mont	P. Seih		0.90	1.37	477
July 29	New	Fayette, W. Va	C. C. Babb		4.07	2.54	7,128
July 30	Madison	Threeforks, Mont	P. Seih		0.10	2.18	1,695
July 30	do	do	A. M. Ryon		0.10	2.17	1,693
July 30	Neosho	Iola, Kan	E. C. Murphy		2.75	0.57	257
July 30	Greenbrier	Alderson, W. Va	C. C. Babb		1.89	1.18	457
July 31	Jefferson	Sappington, Mont	P. Seih		0.80	2.02	1,028
July 31	do	do	A. M. Ryon			2.02	1,028
July 31	James	Buchanan, Va	C. C. Babb		—0.13	0.74	509
August 1	James	do	C. C. Babb		—0.19	1.04	513
August 2	Verdigris	McTaggarts mills, Liberty, Kan	E. C. Murphy		2.40	0.88	107
August 2	North	Lexington, Va	C. C. Babb			1.32	135
August 3	Bruneau	Grand View, Idaho	A. P. Davis		1.33	0.44	50
August 3	Middle creek	Boseman, Mont	A. M. Ryon		0.45	2.32	84
August 3	Neosho	Iola, Kan	E. C. Murphy		3.10	0.98	521
August 5	South	Basic, Va	C. C. Babb			1.30	72
August 6	do	Port Republic, Va	do	1,050	1.22	1.55	114
August 6	North	do	do	418	2.18	1.33	375
August 6	Kansas	Lawrence, Kan	E. C. Murphy	59,841	1.10	0.64	3,025
August 7	South Fork Republican	Benkelman, Neb	O. V. P. Stout		1.75	1.30	23
August 7	North Fork Shenandoah	Riverton, Va	C. C. Babb	1,037		1.72	362
August 7	South Fork Shenandoah	do	do	1,587		2.58	791
August 7	South Platte	Denver, Colo	P. J. Preston	3,840	4.60	3.33	876
August 7	North Fork Republican	Benkelman, Neb	O. V. P. Stout		0.96	2.02	64
August 9	Snake	Montgomerys ferry, Idaho	A. P. Davis		2.80	1.59	5,413
August 9	Frenchman	Wauneta, Neb	O. V. P. Stout		1.38	1.96	62
August 9	do	Palisade, Neb	do		1.50	1.23	68
August 9	do	Wauneta, Neb	do		1.40	2.00	61
August 10	do	Palisade, Neb	do		1.50	1.69	72
August 12	Humboldt	Golconda, Nev	L. H. Taylor	10,780		0.91	11
August 13	Platte	Columbus, Neb	O. V. P. Stout	56,867			[a]75
August 16	Naches	North Yakima, Wash	A. P. Davis	1,000	1.62	1.61	466
August 17	Blue	Manhattan, Kan	O. P. Hood	9,490	6.90		
August 17	Boise	Caldwell, Idaho	G. F. Sherman		3.15	2.35	191
August 17	Weber	Devils Gate, above Uinta, Utah	J. L. Rhead	1,600	0.85	1.40	100
August 18	Chama	Abiquin, N. Mex	P. E. Harroun	2,300	1.30	1.77	209
August 19	Bear	Collinston, Utah	J. L. Rhead	6,000	1.17	2.15	819
August 19	Solomon	Beloit, Kan	W. G. Russell	5,539	3.27	1.64	195
August 19	Rio Grande	Embudo, N. Mex	P. E. Harroun	7,000	8.80	2.34	908
August 19	Yakima	Union Gap, Wash	A. P. Davis	3,300	4.10	1.13	1,070
August 19	Ahtahnum	Mouth, Wash	do			0.63	19
August 20	Yakima	Kiona, Wash	do			1.27	954
August 20	Middle Loup	Above Mullen, Neb	O. V. P. Stout				43
August 20	Republican	Junction City, Kan	W. G. Russell	25,837	4.75	2.72	1,911
August 20	Middle Loup	Mullen, Neb	O. V. P. Stout				120
August 21	Walker	Nordyke, Nev	L. H. Taylor			1.59	177
August 21	Rio Grande	Watertank, New Mexico	P. E. Harroun		5.50	3.92	933
August 21	Middle Loup	Seneca, Neb	O. V. P. Stout				216
August 21	Smoky Hill	Ellsworth, Kan	W. G. Russell	7,980	2.10	1.34	104
August 22	South Platte	Denver, Colo	P. J. Preston	3,830	3.90	2.75	447
August 22	Saline	Beverly, Kan	W. G. Russell	2,730	4.70	1.52	76
August 22	Middle Loup	Thedford, Neb	O. V. P. Stout				284
August 22	Kansas	Lawrence, Neb	E. C. Murphy	59,841	4.10	2.76	17,945
August 23	Dismal	Dunning, Neb	O. V. P. Stout				294
August 23	Middle Loup	do	do				322
August 24	Blue	Manhattan, Neb	O. P. Hood	9,490	5.70	1.61	1,512
August 24	Kansas	Lawrence, Neb	E. C. Murphy	59,841	2.35	1.44	7,869
August 24	North	Glasgow, Va	D. C. Humphreys		0.94	1.55	201
August 25	Sacramento	Jellys Ferry, Cal	A. P. Davis	9,356	5.55	2.41	5,452
August 26	do	Redbluff, Cal	J. B. Lippincott	9,356	0.80		5,500
August 26	Uncompahgre	Uncompahgre, Colo	F. Cogswell	497	3.25	3.38	218
August 26	Potomac	Dam No. 6, Md	C. C. Babb	4,059	0.50		132
August 26	Canal feeder	do	do				93
August 27	Tuolumne	Modesto, Cal	A. P. Davis	1,635	4.00	0.41	294
August 27	Mokelumne	Lodi, Cal	do		1.33	0.78	91
August 27	San Miguel	Seymour, Colo	F. Cogswell	327	3.20	3.08	205
August 27	Kansas	Lawrence, Kan	E. C. Murphy	50,841	1.47	0.86	4,277
August 28	Stanislaus	Oakdale, Cal	A. P. Davis	1,051	2.40	1.39	279
August 28	Dolores	Dolores, Colo	F. Cogswell	562	2.70	2.00	163
August 29	Tuolumne	Lagrange, Cal	A. P. Davis	1,501	4.40	3.20	299
August 29	Middle Loup	Loup city, Neb	O. V. P. Stout				879
August 29	Cimarron	Arkalon, Kan	W. G. Russell		2.30	1.55	16

[a] Estimate.

LIST OF DISCHARGE MEASUREMENTS OF VARIOUS STREAMS IN THE UNITED STATES—Continued.

DATE.	Stream	Locality.	Hydrographer.	Area drained. (Square miles.)	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.							
August 29	Main South Fork	Port Republic, Va	D. C. Humphreys	1,050	1.34	2.09	345
August 29	Rio Las Animas	Durango, Colo	F. Cogswell	812	5.80	1.30	543
August 29	South	Port Republic, Va	D. C. Humphreys		1.34	1.28	87
August 30	San Juan	Arboles, Colo	F. Cogswell	1,394	6.20	1.42	387
August 30	Piedra	do	do	650	3.20	1.94	235
August 31	Arkansas	Hutchinson, Kan	W. G. Russell		2.73	1.86	1,037
August 31	San Joaquin	Herndon, Cal	A. P. Davis	1,637	3.00	0.68	677
August 31	South Loup	Ravenna, Neb	O. V. P. Stout				296
September 1	Medicine	Kiowa, Kan	W. G. Russell		2.60	1.06	40
September 1	Big Goose river	Sheridan, Wyo	W. M. Gilcrest				275
September 2	French Broad	Asheville, N. C	C. C. Babb		4.30	1.84	1,192
September 2	do	Marshall, N. C	do			2.44	1,521
September 2	Kings	Suspension bridge, California	A. P. Davis		9.50	2.50	524
September 3	New	Fayette, W. Va	D. C. Humphreys		1.71	1.43	3,030
September 3	French Broad	Hot Springs, N. C	C. C. Babb			1.93	1,359
September 3	do	Marshall, N. C	do			2.23	1,490
September 3	Kansas	Lawrence, Kan	E. C. Murphy	59,841	3.24	2.14	12,935
September 4	Tejon House creek	Tejon Ranch house, California	A. P. Davis	17		1.00	2
September 4	Mora	Watrous, N. Mex	P. E. Harroun		2.30	1.49	160
September 4	Greenbrier	Alderson, W. Va	D. C. Humphreys		1.36	1.27	106
September 4	Kansas	Lawrence, Kan	E. C. Murphy	59,841	2.63	1.74	9,960
September 5	Humboldt	Elko, Nev	L. H. Taylor	2,840	0.30	0.25	4
September 5	Pigeon	Ironcliff bridge, North Carolina	C. C. Babb			0.90	254
September 5	Arkansas	Pueblo, Colo	F. Cogswell	4,600	0.70	3.35	570
September 5	Neosho	Iola, Kan	E. C. Murphy		2.80	0.79	358
September 5	Rio Grande	San Marcial, N. Mex	P. E. Harroun		6.90	1.99	636
September 6	North Loup	St. Paul, Neb	O. V. P. Stout	4,024	3.04	2.34	816
September 6	Pigeon	Clyde, N. C	C. C. Babb			0.52	159
September 6	James	Buchanan, Va	D. C. Humphreys		—0.48	1.03	397
September 6	Rio Grande	El Paso, Tex	P. E. Harroun	30,000	7.90	1.63	761
September 7	Boise	Foot of Boise canyon, Idaho	G. F. Sherman		1.75	1.44	774
September 7	Middle Loup	St. Paul, Neb	O. V. P. Stout	6,849	1.62	1.81	863
September 7	French Broad	Asheville, N. C	C. C. Babb			1.01	873
September 7	North	Lexington, Va	D. C. Humphreys			0.78	82
September 7	Loup	Columbus, Neb	O. V. P. Stout	13,542	4.17	2.58	1,896
September 7	Verdigris	McTaggarts mills, Liberty, Kan	E. C. Murphy		3.44	1.59	443
September 8	Humboldt	Golconda, Nev	L. H. Taylor	10,780	—0.30	1.20	1
September 8	Middle creek	Bozeman, Mont	A. M. Ryon		0.22	1.53	49
September 9	Tuckaseegee	Dillsboro, N. C	C. C. Babb			2.32	399
September 10	Frenchman	Wauneta, Neb	O. V. P. Stout		0.92	1.65	56
September 10	Rio Grande	Watertank, New Mexico	P. E. Harroun		5.10	3.43	739
September 10	Republican	Above Frenchman	O. V. P. Stout				Dry.
September 10	San Gabriel	Azusa, Cal	J. B. Lippincott	220			34
September 11	South Fork Republican	Benkelman, Neb	O. V. P. Stout				Dry.
September 12	Blue	Manhattan, Kan	A. P. Davis	9,490	3.60	1.48	542
September 12	Republican	Oxford, Neb	O. V. P. Stout			1.09	55
September 13	Little Tennessee	Franklin, N. C	C. C. Babb			1.92	427
September 13	Ogden	Mouth of Ogden valley, Utah	S. Fortier	360	1.45	1.09	57
September 14	Nantahalah	Aquone, N. C	C. C. Babb			0.68	117
September 14	North Platte	North Platte, Neb	O. V. P. Stout	28,517	1.30	1.64	200
September 14	Hiwassee	Murphy, N. C	C. C. Babb			1.54	414
September 14	Weber	Devils Gate, Utah	S. Fortier	1,600	0.85	1.37	94
September 14	Tuolumne	Lagrange, Cal	J. B. Lippincott	1,501	5.80	2.41	1,824
September 15	North Platte	North Platte, Neb	O. V. P. Stout	28,517			200
September 16	Nantahalah	Almond, N. C	C. C. Babb			2.49	187
September 16	Little Tennessee	Judson, N. C	do			2.68	750
September 17	North	Lexington, Va	D. C. Humphreys			0.90	81
September 17	French Broad	Asheville, N. C	do		3.22	1.72	1,006
September 20	Smoky Hill	Ellsworth, Kan	W. G. Russell	7,980	1.50	0.94	26
September 21	Saline	Beverly, Kan	do	2,730	3.85	0.42	13
September 21	Rio Grande	El Paso, Tex	A. P. Davis	30,000	5.70	0.55	76
September 23	Catawba	Fort Mill, S. C	C. C. Babb		1.58	1.66	1,340
September 23	Bear	Colliuston, Utah	S. Fortier	6,000	1.62	2.14	1,058
September 24	Pugatoire	Trinidad, Colo	A. P. Davis			1.06	86
September 25	Arkansas	Pueblo, Colo	do	4,600	0.40	2.30	407
September 26	North Platte	Orin junction, Wyoming	W. M. Gilcrest	14,328	0.65	1.97	508
September 26	Cape Fear	Fayetteville, N. C	C. C. Babb		1.59	1.20	469
September 26	Arkansas	Granite, Colo	A. P. Davis	425	3.10	2.55	215
September 27	Neuse	Smithfield, N. C	C. C. Babb			0.77	110
September 27	Laramie	Uva, Wyo	W. M. Gilcrest	3,179	0.75	1.51	6
September 27	Arkansas	Salida, Kans	A. P. Davis	1,160	0.60	2.90	463
September 28	Gallatin	Logan, Mont	P. Seih		1.20	1.83	741
September 29	Madison	Threeforks, Mont	do		—0.10	1.99	1,440
September 29	Walker	Nordyke, Nev	L. H. Taylor		0.60	1.55	120
September 29	Green	Blake, Utah	A. P. Davis		2.00	1.40	1,938
September 30	Mora	Watrous, N. Mex	P. E. Harroun		1.50	0.66	15
October 1	Grand	Grand Junction, Colo	A. P. Davis	8,644	0.82	2.04	2,059
October 1	Gunnison	do	do	7,935	1.95	0.78	781
October 1	Arkansas	Hutchinson, [illegible]an	W. G. Russell		1.60	0.80	57
October 1	Rio Grande	San Marcial, [illegible], Mex	P. E. Harroun		5.30	1.47	15

LIST OF DISCHARGE MEASUREMENTS OF VARIOUS STREAMS IN THE UNITED STATES—Continued.

DATE.	Stream.	Locality.	Hydrographer.	Area drained. (Square miles.)	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.							
October 1	Big Thompson creek	Home Supply dam, Colorado	P. J. Preston		0.45	0.75	42
October 2	St. Vrain creek	Lyons, Colo	....do	209	2.10	2.78	65
October 2	Dan	Clarksville, Va	C. C. Babb		0.38	1.31	773
October 2	Meherrin	Belfield, Va	....do			1.08	72
October 3	Staunton	Clarksville, Va	....do		−0.07	0.97	533
October 3	Cimarron	Arkalon, Kan	W. G. Russell		2.35	0.98	16
October 3	Rio Grande	El Paso, Tex	P. E. Harroun	30,000	5.70	0.23	26
October 3	Boulder creek	Boulder canyon, Colorado	P. J. Porter	179	0.50	1.04	96
October 4	Arkansas	Canyon city, Colo	A. P. Davis	3,060	2.70	3.70	565
October 5	Sacramento	Redbluff, Cal	J. B. Lippincott	9,256	0.70	2.66	6,100
October 5	....do	Jellys Ferry, Cal	....do	9,259	5.55	2.57	6,046
October 5	Yadkin	Near Holtsburg, N. C	C. C. Babb		1.44	1.22	1,457
October 5	Kansas	Lecompton, Kan	E. C. Murphy	59,840	0.35	2.68	1,286
October 6	Middle creek	Bozeman, Mont	A. M. Ryon		0.28	1.40	53
October 7	Uncompahgre	Fort Crawford, Colo	F. Cogswell	497	2.60	2.05	89
October 8	San Miguel	Fall creek, Colorado	F. Cogswell	327	2.65	2.24	81
October 9	Bear creek	Morrison, Colo	P. J. Porter	170	1.05	2.15	64
October 9	Dolores	Dolores, Colo	F. Cogswell	562	2.50	1.51	89
October 10	Rio Las Animas	Durango, Colo	....do	812	5.40	1.00	328
October 10	Stanislaus	Oakdale, Cal	J. B. Lippincott	1,051	2.11	1.13	193
October 10	South Boulder creek	South Boulder canyon, Colorado	P. J. Preston	125	1.05	1.68	43
October 11	Republican	Junction city, Kan	W. G. Russell	25,837	2.57	1.95	281
October 11	San Juan	Arboles, Colo	F. Cogswell	1,394	5.80	0.86	215
October 11	Piedra	....do	....do	650	2.90	1.47	149
October 11	San Joaquin	Herndon, Cal	J. B. Lippincott	1,637	2.60	0.45	333
October 13	Rio Grande	Del Norte, Colo	F. Cogswell	1,400	1.80	2.53	414
October 14	Ogden	Ogden valley, Utah	S. Fortier		1.53	1.20	78
October 14	Rio Grande	Alamosa, Colo	F. Cogswell			1.19	93
October 14	Bear	Battle Creek,	J. L. Rhead	4,500	1.40	1.87	689
October 15	Chattahoochee	Oakdale, Ga	C. C. Babb	1,560	0.40	1.66	1,096
October 16	Lower Boise	Bridge near Caldwell, Idaho	G. F. Sherman		3.35	3.05	815
October 18	Ocmulgee	Macon, Ga	C. C. Babb	2,425	0.39	1.04	813
October 19	Oconee	Milledgeville, Ga	....do			1.75	1,106
October 22	Green	Green River city, Wyo	W. M. Gilcrest		1.15	1.36	418
October 22	Chattahoochee	Westpoint, Ga	C. C. Babb	1,560		0.51	1,404
October 23	Smoky Hill	Ellsworth, Kan	W. G. Russell	7,980	1.35	0.84	17
October 23	Laramie	Woods Landing, Wyo	W. M. Gilcrest	435	0.80	1.19	49
October 23	Ocmulgee	Macon, Ga	C. C. Babb	2,425	0.20	1.06	767
October 23	Snake	Montgomerys ferry, Idaho	G. F. Sherman		2.28	1.45	4,593
October 24	Rio Grande	Watertank, New Mexico	P. E. Harroun		4.90	2.23	629
October 25	Kansas	Lecompton, Kan	E. C. Murphy	50,840	1.50	1.90	963
October 25	Catawba	Fort Mill, S. C	C. C. Babb		1.51	1.73	1,477
October 26	Yadkin	Near Holtsburg, N. C	....do		1.45	1.33	1,538
October 26	Rio Grande	Embudo, N. Mex	P. E. Harroun	7,000	8.10	1.65	494
October 28	Dan	Clarksville, Va	C. C. Babb		0.65	1.44	1,032
October 28	Staunton	....do	....do		0.28	1.31	861
October 29	Medicine	Kiowa, Kan	W. G. Russell		2.40	0.68	15
October 29	Chama	Abiquiu, N. Mex	P. E. Harroun	2,300	1.10	1.31	73
October 29	Bear	Battle Creek, Mont	A. P. Davis	4,500	1.90	2.12	980
October 31	Solomon	Beloit, Kan	W. G. Russell	5,530	2.10	0.33	8
November 1	....do	....do	....do	5,539	2.93	1.21	78
November 1	Flume	Lawrence, Kan	E. C. Murphy		0.20	1.35	376
November 5	Weber	Devils Gate, Utah	J. L. Rhead	1,600	1.41	2.25	274
November 5	San Gabriel	Azusa, Cal	J. B. Lippincott	220	1.50		46
November 6	Potomac	Point of Rocks, Md	C. C. Babb	9,654	0.80	0.51	1,202
November 9	South Platte	Denver, Colo	P. J. Preston	3,840	4.30	2.56	430
November 11	Republican	Junction city, Kan	W. G. Russell	25,837	2.60	1.95	286
November 11	Ogden	Ogden, Utah	S. Fortier	360	1.55	1.26	71
November 12	Saline	Beverly, Kan	W. G. Russell	2,730	4.30	1.00	56
November 13	Tejon	Foothills, California	J. B. Lippincott			1.84	256
November 13	Arkansas	Hutchinson, Kan	W. G. Russell		1.50	0.73	46
November 13	Tejon House creek	Tejon Ranch house, California	J. B. Lippincott	17	0.40	1.86	346
November 15	Neosho	Iola, Kan	E. C. Murphy		2.40	0.56	207
November 15	Verdigris	McTaggarts mills, Liberty, Kan	....do		2.70	1.16	218
November 16	Mora	Watrous, N. Mex	P. E. Harroun		1.90	0.66	39
November 17	Rio Grande	San Marcial, N. Mex	....do		7.20	2.17	674
November 18	Yakima	Union gap, Washington	S. Storrow	3,300	4.66	1.63	1,889
November 18	Uncompahgre	Fort Crawford, Colo	F. Cogswell	497	2.55	2.23	92
November 20	South Platte	Orchard, Colo	P. J. Preston	12,260	4.00	2.53	829
November 20	Dolores	Dolores, Colo	F. Cogswell	562	2.40	1.45	75
November 21	South Platte	Green City bridge, Colo	P. J. Preston	12,200	2.30	2.61	872
November 21	Rio Grande	El Paso, Tex	P. E. Harroun	30,000	6.90	1.55	892
November 24 (1894)	Satas	South Branch, Wash	A. P. Davis		2.00	1.25	13
November 24	Kings	Red Mountain, California	J. B. Lippincott		3.80	0.71	248
November 24	Rio Las Animas	Durango, Colo	F. Cogswell	812	5.20	0.89	200
November 25	San Joaquin	Herndon, Cal	J. B. Lippincott	1,637	2.55	0.38	270
November 25	Piedra	Arboles, Colo	F. Cogswell	650	2.80	1.31	115
November 25	San Juan	....do	....do	1,394	5.90	0.97	253
November 26	Chama	Abiquiu, N. Mex	P. E. Harroun	2,300	1.80	0.64	77
November 27	Merced	Merced Falls, Cal	J. B. Lippincott			3.02	125
November 28	Tuolumne	Lagrange bridge, Cal	....do	1,501	4.20	0.68	129
November 28	Rio Grande	Embudo, N. Mex	P. E. Harroun	7,000	8.40	1.82	617

LIST OF DISCHARGE MEASUREMENTS OF VARIOUS STREAMS IN THE UNITED STATES—Continued.

Date.	Stream.	Locality.	Hydrographer.	Area drained. (Square miles.)	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1895.							
November 29	Stanislaus	Oakdale, Cal	J. B. Lippincott	1,051	2.13	0.90	147
November 29	West Gallatin	Williams ranch, Montana	A. M. Ryon			2.33	398
November 29	South Platte	Denver, Colo	P. J. Preston	3,840	3.90	2.37	303
November 30	Jefferson	Sappington, Mont	P. Seih		0.95	1.99	1,200
November 30	Tuolumne	Modesto, California	J. B. Lippincott	1,635	3.42	0.39	212
November 30	Rio Grande	Watertank, New Mexico	P. E. Harroun		4.00	2.84	639
November 30	South Platte	Deansbury, Colo	L. R. Hope	2,600	4.00	4.03	197
December 1	do	do	do	2,600	3.20	2.78	102
December 2	Naches	North Yakima, Wash	S. Storrow	1,000		1.44	349
December 2	Kings	Kingsburg, Cal	J. B. Lippincott	1,742	3.25	0.60	256
December 4	Arkansas	Lajunta, Colo	A. P. Davis	12,200	1.50	1.61	455
December 4	Rio Grande	El Paso, Tex	do	30,000	7.50	1.37	423
December 5	Dan	Clarksville, Va	C. C. Babb		1.12	1.60	1,382
December 5	Staunton	do	do		0.61	1.25	1,151
December 6	Smoky Hill	Ellsworth, Kan	W. G. Russell	7,980	1.35	0.94	18
December 7	South Platte	Deansbury, Colo	L. R. Hope	2,600	3.60	3.59	100
December 7	Cape Fear	Fayetteville, N. C	C. C. Babb		2.90	1.56	1,109
December 8	Frenchman	Palisade, Neb	O. V. P. Stout				116
December 8	South Platte	Deansbury, Colo	L. R. Hope	2,600	3.65	3.71	168
December 9	Bear	Collinston, Utah	S. Fortier	6,000	1.95	2.21	1,397
December 10	Yadkin	Holtsburg, N. C	C. C. Babb		1.74	1.57	2,415
December 10	Weiser	Weiser canyon, Idaho	G. F. Sherman	1,670	1.65	0.80	171
December 11	Payette	Payette, Idaho	do		0.36	2.21	1,003
December 13	Solomon	Beloit, Kan	W. G. Russell	5,530	2.85	1.19	109
December 13	Ocmulgee	Macon, Ga	C. C. Babb	2,425	1.56	1.46	1,530
December 13	Mora	Watrous, N. Mex	P. E. Harroun		1.90	1.01	61
December 13	Republican	Junction city, Kan	W. G. Russell	25,837	2.95	2.02	378
December 14	Chattahoochee	Oakdale, Ga	C. C. Babb	1,560	0.69	1.73	1,380
December 14	Rio Grande	San Marcial, N. Mex	P. E. Harroun		7.20	3.12	602
December 14	Humboldt	Elko, Nev	L. H. Taylor	2,840	0.55	0.62	19
December 14	Saline	Beverly, Kan	W. G. Russell	2,730	4.60	1.19	79
December 14	South Platte	Deansbury, Colo	L. R. Hope	2,600	3.80	3.88	183
December 16	Rio Grande	El Paso, Tex	P. E. Harroun	30,000	6.80	1.13	266
December 17	Colorado	Austin, Tex	C. C. Babb			1.10	507
December 18	Bartons spring	do	do			0.68	25
December 19	San Marcos	San Marcos, Tex	do			1.68	89
December 20	South Platte	Deansbury, Colo	L. R. Hope	2,600	3.35	3.51	135
December 20	Arkansas	Hutchinson, Kan	W. G. Russell		2.15	1.33	125
December 20	Comal	New Braunfels, Tex	C. C. Babb			3.81	328
December 21	Medicine	Kiowa, Kan	W. G. Russell		2.65	1.23	54
December 21	Rio Grande	El Paso, Tex	C. C. Babb	30,000	7.42	1.50	386
December 21	San Antonio	San Antonio, Tex	C. C. Babb				43
December 21	San Pedro	do	do				9
December 21	Bruneau	Grand View, Idaho	A. J. Wiley			0.85	127
December 22	South Platte	Orchard, Colo	P. J. Preston	12,260	3.83	2.34	667
December 23	Saline	Beverly, Kan	W. G. Russell	2,730	4.10	0.57	25
December 23	Sabinal	Sabinal, Tex	C. C. Babb				69
December 23	Leona	Uvalde, Tex	do				11
December 24	Las Moras springs	Fort Clark, Tex	do			0.41	21
December 24	Del Rio ditch	Del Rio, Tex	do			0.79	19
December 24	San Felipe spring	do	do			2.00	80
December 27	Solomon	Beloit, Kan	W. G. Russell	5,539	2.80	1.07	105
December 27	Republican	Junction city, Kan	do	25,837	3.18	2.38	445
December 27	Rio Grande	El Paso, Tex	C. C. Babb	30,000	7.42	1.50	386
December 28	Smoky Hill	Ellsworth, Kan	W. G. Russell	7,980	1.30	0.95	18
December 28	Gila	Buttes, Arizona	A. P. Davis	13,750	2.35	3.70	585
December 28	Florence canal	Whites ranch, Arizona	do		2.00	0.78	8
December 31	Gila	Buttes, Arizona	do	13,750	2.23	3.55	519
December 31	Arkansas	Hutchinson, Kan	W. G. Russell		1.75	0.64	40
1896.							
January 5	Gila	Buttes, Arizona	C. C. Babb	13,750	2.10	2.93	307
January 6	South Platte	Fifteenth Street bridge, Denver, Colo	P. J. Preston	3,840	3.60	2.15	183
January 8	Yakima	Union Gap, Wash	S. Storrow	3,300	5.60	2.83	3,880
January 10	Rio Grande	San Marcial, N. Mex	P. E. Harroun		7.40	3.20	701
January 11	do	El Paso, Tex	do	30,000	6.20	0.93	151
January 12	South Platte	Deansbury, Colo	L. R. Hope	2,600	3.05	2.77	94
January 12	Gila	Buttes, Arizona	C. C. Babb	13,750	2.03	2.30	436
January 14	Chattahoochee	Oakdale, Ga	B. M. Hall	1,500	0.70	1.53	1,360
January 14	Solomon	Beloit, Kan	W. G. Russell	5,539			5
January 14	do	do	do	5,539	2.75	1.01	115
January 15	Republican	Junction city, Kan	do	25,837	3.50	1.91	504
January 16	Florence canal	Whites ranch, Arizona	A. P. Davis		2.80	2.14	167
January 16	Saline	Beverly, Kan	W. G. Russell	2,730	4.10	0.60	33
January 17	Queen creek	Queen Creek Dam site, Arizona	A. P. Davis		0.80	0.90	3
January 17	Arkansas	Hutchinson, Kan	W. G. Russell		2.35	1.65	494
January 18	South Platte	Deansbury, Colo	L. R. Hope	2,600	3.05	2.86	94
January 19	Chama	Abiquiu, N. Mex	P. E. Harroun	2,300	1.50	1.44	129
January 19	Gila	Buttes, Arizona	C. C. Babb	13,750	1.92	3.00	396
January 20	Sacramento	Jellys Ferry, Cal	J. B. Lippincott	9,356	29.50		127,000
January 20	do	Redbluff, Cal	do	9,356	23.50	7.65	136,000
January 21	do	Jellys Ferry, Cal	do	9,356	25.90		105,000
January 21	do	Redbluff, Cal	do	9,356	20.80	7.60	109,432
January 22	Rio Grande	San Marcial, N. Mex	P. E. Harroun		7.50	3.29	767
January 22	Sacramento	Jellys Ferry, Cal	J. B. Lippincott	9,356	22.70		82,000
January 22	do	Redbluff, Cal	do	9,356	17.70	7.56	83,558

LIST OF DISCHARGE MEASUREMENTS OF VARIOUS STREAMS IN THE UNITED STATES—Continued.

DATE.	Stream.	Locality.	Hydrographer.	Area drained. (Square miles.)	Gauge height. (Feet.)	Mean velocity. (Feet per second.)	Discharge. (Second-feet.)
1896.							
January 22	Smoky Hill	Ellsworth, Kan	W. G. Russell	7,980	1.42	1.00	26
January 23	Rio Grande	El Paso, Tex	P. E. Harroun	30,000	7.30	1.64	379
January 25	Gila	Buttes, Arizona	C. C. Babb	13,750	1.79	2.21	270
January 25	Owyhee	Owyhee bridge, Oregon	G. F. Sherman	9,875	1.60	1.30	408
January 25	Malheur	Vale, Ore	do	9,900	3.20	1.56	852
January 26	Humboldt	Golconda, Nev	L. H. Taylor	10,780	1.00	0.92	55
January 26	Gila	Buttes, Arizona	C. C. Babb	13,750	1.78	2.46	247
January 26	do	do	do	13,750	1.78	2.92	275
January 26	do	do	A. P. Davis	13,750	1.78	2.83	268
January 27	South Platte	Deansbury, Colo	L. R. Hope	2,600	2.90	2.86	90
January 27	Humboldt	Oreana, Nev	L. H. Taylor			1.08	49
January 27	Republican	Junction city, Kan	W. G. Russell	25,837	3.12	1.74	410
January 27	Weiser	Weiser canyon, Idaho	G. F. Sherman	1,670	4.00	2.88	1,806
January 27	Florence canal	Whites ranch, Arizona	J. F. Appleby		2.98	1.87	80
January 27	do	Nicholas gate, Arizona	do			2.60	95
January 28	Ocmulgee	Macon, Ga	B. M. Hall		5.52	1.63	3,436
January 28	Saline	Beverly, Kan	W. G. Russell	2,730	4.05	0.77	31
January 29	Arkansas	Hutchinson, Kan	do		2.80	1.79	791
January 31	Solomon	Beloit, Kan	do	5,530	2.65	1.22	125
February 1	Tejon House creek	Tejon Ranch house, California	J. B. Lippincott	17	2.50	2.09	8
February 2	do	do	do	17	2.50	2.57	18
February 3	Fort Tejon creek	Near Rose Station, California	do			1.92	3
February 3	Florence canal	Nicholas gate, Arizona	A. P. Davis			2.64	170
February 4	Consolidated canal	Near head	do		1.70	2.23	187
February 4	South Platte	Deansbury, Colo	L. R. Hope	2,600	3.18	3.29	116
February 4	Arizona canal	Near head	A. P. Davis		2.70	4.10	908
February 8	Gila	Buttes, Arizona	H. G. Heisler	13,750	1.73	2.69	317
February 9	do	do	J. F. Appleby	13,750	1.70	2.23	247
February 10	Republican	Junction city, Kan	W. G. Russell	25,837	3.70	2.32	745
February 11	South Platte	Deansbury, Colo	L. R. Hope	2,600	3.10	3.02	101
February 11	Humboldt	Golconda, Nev	L. H. Taylor	10,780	1.52	1.35	93
February 12	Gila	Buttes, Arizona	H. G. Heisler	13,750	1.73	2.37	251
February 12	Rock creek	Near Battle Mountain, Nevada	do		1.90	1.07	13
February 12	Solomon	Beloit, Kan	W. G. Russell	5,539	2.75	1.13	123
February 13	Arkansas	Hutchinson, Kan	do		2.15	1.74	309
February 13	Naches	Northern Pacific Railroad bridge, Wash.	Samuel Storrow		1.85	1.93	663
February 14	Saline	Beverly, Wash	W. G. Russell	2,730	4.25	0.96	46
February 14	Rio Grande	San Marcial, N. Mex	P. E. Harroun		7.30	3.63	570
February 15	do	El Paso, Tex	do	30,000	7.10	1.49	282
February 18	Gila	Buttes, Arizona	W. J. Brash	13,750	1.74	2.46	260
February 19	South Platte	Green City bridge, Colorado	H. A. Sumner				624
February 19	do	Orchard, Colo	do	12,260	3.90	2.33	609
February 19	do	Deansbury, Colo	L. R. Hope	2,600	2.97	2.84	91
February 19	Humboldt	Elko, Nev	L. H. Taylor	2,840	0.72	1.30	52
February 19	San Gabriel	Azusa, Cal	J. B. Lippincott	220	1.35	1.06	38
February 22	Gila	Buttes, Arizona	W. J. Brash	13,750	1.75	2.29	253
February 23	South Platte	Deansbury, Colo	L. R. Hope	2,600	3.42	3.58	145
March 15	Loup	Columbus, Neb	O. V. P. Stout	13,542	3.88		1,550
March 18	South Platte	Deansbury, Colo	L. R. Hope	2,600	3.07	3.01	97
March 19	Smoky Hill	Ellsworth, Kan	W. G. Russell	7,980	1.24	0.88	16
March 20	South Platte	Deansbury, Colo	L. R. Hope	2,600	3.75	3.89	184
March 22	Arkansas	Pueblo, Colo	F. Cogswell	4,600	0.50	2.70	470
March 22	San Gabriel	Azusa, Cal	J. B. Lippincott	220	2.27	2.34	105
March 30	South Platte	Deansbury, Colo	L. R. Hope	2,600	5.15	5.51	372
April 4	Middle Creek	Middle Creek Canyon, Mont	A. M. Ryon		0.10	1.05	29
April 13	Smoky Hill	Ellsworth, Kans	W. G. Russell	7,980	3.04	1.75	387
April 14	Saline	Beverly, Kans	do	2,730	9.70	2.79	693
April 14	Neosho	Iola, Kans	E. C. Murphy		3.40	0.97	664
April 15	Arkansas	Hutchinson, Kans	W. G. Russell		1.67	1.10	78
April 15	Verdigris	Near Liberty, Kans	E. C. Murphy		3.40	1.47	368
April 16	Republican	Junction City, Kans	W. G. Russell	25,837	6.50	3.62	3,604
April 17	Solomon	Beloit, Kans	do	5,539	4.58	2.26	734

INDEX.

A.

Page.

- Abandoned farms resulting from successive droughts 120
- Abert lake, described 208, 212
- Absaroka range, waters from 245, 253
- Adams, A. L., estimated discharge of Umatilla river 173, 216
- Adamsville, Utah, agricultural lands in vicinity of 222
- Agricultural ditch, Colorado 102
- Agriculture, Mexican system of 195
- Akron, Colo., flowing wells at 132
- Alamosa, Colo., flowing wells at 99
  - Rio Grande at 107
- Albright, Mont., flowing wells at 161
- Albuquerque valley, New Mexico 194
- Alessandro district, California 72, 74
- Alfalfa ditch, Colorado 108
- Alfalfa, applying water for 23, 26
  - produced without irrigation 151, 220
- Alfalfa, production by states and territories:
  - Arizona 22
  - California 33
  - Colorado 90
  - Idaho 136
  - Montana 157
  - Nevada 177
  - New Mexico 193
  - Oregon 202
  - Utah 218
  - Washington 236
  - Wyoming 248
- Alkaline salts, presence in soil of 187
- Alkali lakes, Modoc county, Cal 63
- Alkali lake, Washington, described 243
- Alliance ditch, Nebraska, description of 268
- Althouse, Ore., irrigation in vicinity of 210
- Alturas, Cal., canals at 64
- Amargosa desert, Nevada 188
- Amazon canal, Kansas, taken from below the bed of the Arkansas river. 275
- American falls on Snake river 148
- American fork, Utah, discharge of 232, 234
- Amity canals, Colorado 126
- Anaheim Union Water Company, California 66
- Animas river, canals taken from 200
- Animas Valley Ditch Company, Colorado 116
- Antelope creek, Idaho 141
  - valley, crops of forage in 57
- Antelope Valley Water Company, California 57
- Annual expenditures 10
- Apishapa river 119
- Applegate, Ore., irrigation in vicinity of 210
- Applying water, methods of 20
- Arapahoe Irrigation Company, Nebraska 272
- Arbitration, for the control of Utah lake 229
- Area irrigated 1
- Arikaree river, Colorado, amount of water available for irrigation 101
- Arizona canal, Arizona, diverted water from Salt river by 28
- Arizona:
  - Counties of 22
    - Apache 24, 25
    - Cochise 25
    - Gila 25
    - Graham 25, 26
    - Maricopa 26, 27, 28, 29
    - Mohave 29
    - Pima 29, 30
    - Pinal 30, 31
    - Yavapai 31, 32
    - Yuma 32

Page.

- Arkansas river, deficiencies of water supply of 123
  - in Colorado, discharge of 104, 111, 123, 126, 296
  - in Kansas, unsatisfactory for irrigation purposes 275, 312
- Ar[illegible]ette ditch, Colorado 114
- Arrowhead Reservoir Company, California 60, 74
- Artesian areas 17, 18
- Artesian water, advantages of, for irrigation 17
- Artesian wells, cost of 14
- Artesian wells, described by states and territories:
  - Arizona 18
  - California, depth of 11, 72
  - Kern county, Cal 50
  - Lake county, Cal 56
  - Merced county, Cal 63
  - San Felipe valley, California 69
  - Santa Clara county, Cal 80
  - Stockton, Cal 78
  - Surprise valley, California 64
  - Tulare county, Cal 86
  - Colorado 98
  - Idaho 139
  - Kansas 277
  - Montana 161
  - Nebraska 272
  - North Dakota 261, 262
  - New Mexico 197
  - Nevada 181
  - South Dakota 264
  - Texas 282
  - Washington 239, 247
- Ash creek, California, irrigation from 55
- Ash spring, Nevada, water supply of 187
- Ashland, Ore., irrigation near 210
- Ashley fork, ditches taken from 232
- Asotin creek, ditches taken from 240
- Atanam valley, description of 246
- Augusta, Mont., discharge of Sun river at 163
- Austin, Nev., mining and stock raising at 186
- Austin, Tex., small ditches taken from springs in vicinity of 280
- Azusa ditch, California 59

B

- Baca Extension ditch, Colorado 119
- "Bad lands" of Wyoming 255
  - Idaho described 151
- Baker, Ore., flowing wells in vicinity of 205
- Barley, average production of, by states:
  - Arizona 22
  - California 33
  - Colorado 90
  - Idaho 136
  - Montana 157
  - Nevada 177
  - New Mexico 193
  - Oregon 202
  - Utah 218
  - Washington 236
  - Wyoming 248
- Basin system, disadvantage of the use of 20
- Battle mountain, Nevada, flowing wells at 186
- Battle Creek, Idaho, measurements of Bear river at 153
- Bear creek Colorado, measurements made at Morrison on 114, 295
  - Oregon, abundant water supply of 210
  - at base of foothills, California, discharge of 62
- Bear lake, Idaho, drainage area of 142
- Bearlodge range, Wyoming 252

Page.
Bear river at Collinston, Utah, discharge of 223, 303
        Battle Creek, Idaho, discharge of 154, 297
      upper, Idaho, drainage area of 142
      Idaho, surveys below Gentile valley from 153
      valley, the great hay ranches of 229, 256
Bear Valley Company, California 71
        reservoir, California 71
Beardsley canal, California 53
Beaver county, Okla., ditches taking water from Cimarron river 277
Beaver creek, ditches taken from 223
        North Dakota, land irrigated from 260
Beaver, Utah, altitude of agricultural lands in vicinity 222
Beaverhead river, Montana, natural irrigation along 161
Beavertail ridge, Washington 246
Bed Rock Mutual Ditch Company, Colorado 126
Beeman ditch, Colorado 133
Belmont Irrigating Canal and Water Power Company, Nebraska 268
Belle Fourche river, South Dakota, diverting water from 263
        small ditches taken from 252
Bellevue, Idaho, water taken from Wood river in vicinity of 152
Bellota, Cal., Calaveras river at 78
Belt mountains, water supply of 162
"Bench lands" in Cascade county, Mont 162
Benkelman, Neb., ditches in vicinity of 272
Big Camas prairie, description of 151
Big Cheyenne river, small ditches taken from 256
Big Cut ditch, Colorado 130
Big Dalton canyon, California 60
Bighole river, Montana, water supply of 161, 171, 175
Bighorn range, perennial streams from 255
Big Klamath ditch, Oregon 211
Big Lost river, Idaho 141, 149
Big Meadows, Nevada, fertility of 186
Big Sandy creek, Colorado, described 104, 115, 120
Big Sandy, Wyoming, limited irrigation along 255
Big Smoky valley, Nevada, irrigation from springs in 188
Big Thompson creek, Colorado, ditches from 116, 118
Billings, Mont., ditches taken from the Yellowstone at 176
        deep wells at 161
        canals in vicinity of 176
Birch creek, Idaho, water supply of 151
Birchwood creek, Nebraska, discharge of 270
Bishop creek, Nevada, reservoir sites of 184
        ditch, California 50
Bitterroot, Montana, valley of 172
        mountains, Idaho 136
Blacks creek, Idaho, reservoirs on 150
Blackfoot river, Idaho, water supply of 144
Blackrock desert, Nevada 186
Black Hills, water supply and grazing 252, 263
Blanco river, Texas, ditches taken from 281
Bloomington Canyon creek, water taken from 143
Blue creek, Nebraska, discharge of 269, 270
Blue Mountain Irrigation and Improvement Company, Oregon 216
Blue mountains, beneficial influence to agriculture of 203
Bob Creek canal, Colorado 115, 124
Boca, Nev., precipitation at 180
      Cal., discharge of Truckee river at 190
Boise, Idaho, artesian wells in vicinity of 139
Boise river, Idaho, water supply of 149, 297
        canals taken from 141
        discharge, estimated by A. D. Foote, of 141
Boise City and Nampa Canal Company, Idaho 141
Bonneville lake, described by United States Geological Survey 178
Boulder creek, Colorado, water supply of 134, 295
Bozeman, Mont., canals in the vicinity of 168
Broadford, Idaho, canals taken from Wood river at 152
Broadway canal, Arizona 28
Brazos river, Nevada, irrigation near the head waters of the 279
Brokenbow, Neb., irrigation in vicinity of 271
Brownboro, Ore., irrigation in vicinity of 210
Browns Valley irrigation district, California 89
Bruneau river, Idaho, water supply of 155, 184, 298
Bucket wheels, along Klamath river, California 81
Buckeye canal, Arizona 28, 29
Buena Vista, Colo., measurements of Cottonwood creek near 104
Bull ditch, Washington, taken from Yakima river 242
"Bunch grass", for pasturage in Idaho 137
Bunkerville, Nev., expense of irrigation in vicinity of 187
Burgess canal, Idaho, gauging of 147
Burnt river, Oregon, use of water supply in gold washing 206
Butte, Mont., city of 175

C.

Page.
Cache creek, California, drainage of Clear lake 55
Cache valley, Idaho, measurements of Bear river in 153
Cache la Poudre at Fort Collins, Colo., drainage area and discharge of 116, 117
Cache la Poudre canal, Colorado 135
Calaveras river, California, discharge of 78
California:
    Counties of 36, 37
        Alameda 41
        Alpine 41, 42
        Amador 42
        Butte 42, 43
        Calaveras 43
        Colusa 43, 44, 45
        Contra Costa 45
        Del Norte 45
        Eldorado 45
        Fresno 45, 46, 47, 48, 49
        Humboldt 49
        Inyo 49, 50
        Kern 50, 51, 52, 53, 54, 55
        Lake 55
        Lassin 55, 56
        Los Angeles 56, 57, 58, 59, 60
        Marin 61
        Mariposa 61
        Mendocino 61
        Merced 61, 62, 63
        Modoc 63, 64
        Mono 64
        Monterey 64
        Napa 65
        Nevada 65
        Orange 65, 66
        Placer 67
        Plumas 67
        Sacramento 67, 68
        San Benito 68, 69
        San Bernardino 69, 70, 71, 72, 73, 74
        San Diego 75, 76, 77, 78
        San Francisco 78
        San Joaquin 78, 79
        San Luis Obispo 79
        San Mateo 79
        Santa Barbara 79
        Santa Clara 79, 80
        Santa Cruz 80
        Shasta 80, 81
        Sierra 81
        Siskeyou 81
        Solano 82
        Sonoma 82
        Stanislaus 82, 83
        Sutter 83
        Tehama 83
        Trinity 83, 84
        Tulare 84, 85, 86, 87
        Tuolumne 88
        Ventura 88
        Yolo 88, 89
        Yuba 89
California, water measurements by state engineering department of 37
California Water and Mining Company, California 45
Caliente creek at base of foothills, California, discharge of 51
Calispell, Wash., drainage and irrigation in the vicinity of 244
Camas creek, Idaho, drainage basin of 149
Cameron ditch, Washington 243
Campbell ditches, Nevada, water taken from Warm springs 192
Camp Clarke, Neb., canals taken from the North Platte at 268
Campverde, Ariz., ditches at 32
Canadian river, New Mexico, drainage area of 193
Canyon creek, Idaho, water supply of 150
Canyon, Colo., ditches taken from the Arkansas at 110
Canyon Ferry, Mont., discharge of Missouri at 160
Capay ditch, California 89
Capitan mountains, streams flowing from 198
Carson river, California and Nevada, lands and ditches on 41, 182, 187
Carpenter, Prof. L. G., reports and computations 98, 117, 294
        discharge near Empire, Nev., of 183
Carson valley, Nevada, flowing wells in 181
        reservoir sites in 188
Cascade range, Oregon 202

Page.

- Castle creek, California, discharge of 81
- Castle Rock canal, Nebraska 268
- Castlewood dam, Colorado, description of 109
- Castroville, Cal., flowing wells near 64
- Catlin ditch, Colorado 124
- Cedar valley, Utah, agricultural possibilities of 232
- Cement canals in California 70
- Central irrigation district, California 44, 45
- Centerville and Kingsburg canal, California 49
- Cereals, method of irrigating 20
  - Arizona 22
  - California 46
  - Colorado 90, 96
  - Idaho 136
  - Montana 157
  - New Mexico 193
  - Nevada 177
  - Oregon 202
  - Utah 218
  - Washington 236
  - Wyoming 248
- Chama river, New Mexico, water supply of 199
- Charleston peak, Nevada, altitude of 188
- Chaves county, N. Mex., taken from Lincoln county 198
- Check system, irrigation by 20, 61
- Cherry Slough Water and Irrigation ditch, California 44, 45, 83
- Cherry creek, Colorado, water supply of 100
  - Nevada, ditches taken from 192
- Cherokee ditch, California 43
- Chesterfield, Idaho, agriculture in the vicinity of 144
- Chestnut valley, Montana, the extent of 162
- Cheyenne river, water supply of 252
- Cheyenne, Colo., wells at 99
- Cheyenne wells, water supply of 104
- Chewaucan valley, abundant water supply of 213
- Chimney Rock canal, Nebraska 268
- Chititi ditch, Colorado 119
- Choteau, Mont., measurement of Teton river at 164
- Chowchilla creek, California, flowing well near 47
  - discharge of, at base of foothills, California 62
- Chugwater Creek valley, irrigation from Laramie river 254
- Churchill valley, Nevada, alfalfa in 187
- Church ditch, Colorado 115
- Cimarron creek, Colorado, water supply of 122
  - New Mexico, canals taken from 196
- Cinnabar, Mont., Yellowstone river, measured at 173
- Citrus belt district, California 74
- Claremount Land and Irrigation Company canal, Kansas, taken from Cimarron river 276
- Clarke fork, of the Columbia 165, 172, 244
- Clarkston creek, Utah, storage of surplus water of 224
- Classification of farms according to size 7
- Clear creek, California, discharge near mouth of 81
  - Colorado, measurements near Granite, Colo 104, 114
  - Wyoming, ditches from 254, 255
- Clear lake, California, description of 55, 88
- Clearwater river, Idaho 150, 151, 152
- Cloud Peak, Wyoming, favorable reservoir sites in vicinity of 255
- Clover valley, Nevada, water supply of 184
- Coast range 202
- Cochetopah creek, Colorado 131
- Coconino county, Ariz 31
- Coeur d'Alene lake, Idaho 150
- Cold Creek valley, Nevada 189
- Collinston, Utah, Bear river at 222
- Colonies in vicinity of Bakersfield, Cal 50
- Colonies, of Merced county, Cal 61
- Colorado—counties of:
  - Arapahoe 101, 102
  - Archuleta 102
  - Baca 102
  - Bent 102
  - Boulder 103, 104
  - Chaffee 104
  - Cheyenne 104
  - Clear Creek 105
  - Conejos 105, 106
  - Costilla 106, 107
  - Custer 107
  - Delta 107, 108
  - Dolores 108
  - Douglas 108, 109

Colorado, counties of—Continued.

Page.

  - Eagle 109
  - Elbert 109
  - El Paso 110
  - Fremont 110, 111
  - Garfield 112, 113
  - Gilpin 113
  - Grand 113
  - Gunnison 113
  - Hinsdale 113
  - Huerfano 113
  - Jefferson 114, 115
  - Kiowa 115
  - Kit Carson 115
  - Lake 115, 116
  - La Plata 116
  - Larimer 116, 117, 118
  - Las Animas 119
  - Lincoln 119, 120
  - Logan 120, 121
  - Mesa 121, 122
  - Montezuma 122
  - Montrose 122
  - Morgan 122, 123
  - Otero 123, 124
  - Ouray 124
  - Park 125
  - Phillips 125
  - Pitkin 125
  - Prowers 126
  - Pueblo 126, 127
  - Rio Blanco 127
  - Rio Grande 127, 128, 129
  - Routt 129, 130
  - Saguache 131
  - San Juan 131
  - San Miguel 131
  - Sedgwick 131, 132
  - Summit 132
  - Washington 132
  - Weld 132, 133, 134
  - Yuma 135
- Colorado and Kansas canal, Colorado 126
- Colorado basin, in Utah 219
- Colorado Consolidated Land and Water Company, Colorado 122
- Colorado Land and Water canal, Colorado 115
- Colorado river, Arizona, water supply of 24, 29, 288
- Columbia river, Oregon, canyons of 202
  - Washington, water supply of 237
- Columbia and Yakima Irrigation Company canal, Washington 247
- Columbia Valley Land and Irrigation Company, Oregon 216
- Colville Indian reservation, Washington 244
- Colville valley, Washington, agricultural areas of 244
- Comanche Irrigation Company, Texas, taken from Leona river 281
- Concho river, Texas, small expense to divert water from 279
- Conducting water, method of 19
- Conejos, Colo., altitude of 105
- Conflicts over proper distribution of water 100
- Coolidge, Kan., flowing wells in vicinity of 277
- Corn, methods of irrigating 20
  - Arizona 22
  - California 33
  - Colorado 90
  - Idaho 136
  - Montana 157
  - Nevada 177
  - New Mexico 193
  - Oregon 202
  - Utah 218
  - Washington 236
  - Wyoming 248
- Corporations, renting of water from 139
- Cortez, Colo., canals in vicinity of 122
- Cost of canal construction 11
  - irrigation 8, 10
- Costilla creek, Colorado, drainage area of 106
- Costilla ditch, Colorado 107
- Cosumnes river at Live Oak suspension bridge, California, discharge of 68
- Cottonwood creek near Buena Vista, Colo 104
- Coulees, defined 172, 237
- Council valley, Idaho, water taken from Weiser river 155
- Cow creek, California, discharge of 80
- Crab creek, Washington, disappearance by evaporation of 243

Page.
Craig, Mont., discharge of Missouri river at 170
Crazy Woman creek, Wyoming, great benefit of late irrigation on 254
Crooked River valley, Oregon, irrigable land of 207
Crocker-Huffman Land and Water Company, California 63
Crops, character and value of 4, 5
Cross, Whitman, artesian well report, by 98
Crow creek, Colorado, water supply along 133
Crystal springs, Nevada, water supply of 187
Cub river, Utah, ditches taken from 225
Cucharas canyon, Colorado, Huerfano measured in 127
Culbertson, Neb., ditches in vicinity of 272
Culbertson Irrigation and Water Power Company, Nebraska 272
Culebra creek, Colorado 106
Cuyamaca reservoir, California, capacity of 76, 77

D.

Dakota sandstone, wells obtained in 264
Dallas, Ore., average annual rainfall at 204
  irrigation in vicinity of 217
Dayton, Nev., water utilized by mill owners at 187
Dayton Ditch Company, Nevada 186
Davidson, Samuel A., observations at head works of Arizona canal, by 26
Deansbury, Colo., discharge of South Platte at 125
  gauging station at 114
Débris from mines in Montana, injuring the land 165, 175
Dearborn river, Montana 168
Death valley, California 49
Deep Creek mines, Utah 232
Deer creek, California, discharge of, at base of foothills 86
Deer Lodge creek, Montana, ditches taken from 165, 175
Deficiency of water 12
Dell, Ore., barren desert in vicinity of 213
Dillon, Mont., wells at 161
Disappointment creek, Colorado, water diverted from 108
Discharge of artesian wells 14, 15
Dismal river, Nebraska, water supply of 269
Ditches, cement and earth 19
Ditches in Idaho, construction of 138
Divisions, Colorado, divided into water districts or 94
Dixie canal, Idaho 141
Dolores river, Colorado, ditches taken from 122
  Utah, small canals taken from 226
Donner lake, Nevada, drainage of 189
Dorsey, N. Mex., irrigating systems in vicinity of 196
Dove creek, Texas, ditches taken from 280
Drainage in California, accompanying irrigation 46
Del Norte, Colo., Rio Grande discharge above 128
  canal, Colorado 129
Del Rio, Tex., cost of and method of applying water at 281
Delta, Colo., fruit culture at 108
Deming, N. Mex., shallow wells in vicinity of 195
Denver, Colo., canals in vicinity of 101
  city ditch of 102
  wells in vicinity of 98
Denver Water Storage Company, Colorado 109
Depth of artesian wells 14
Deschutes river, Oregon, abundant water supply of 207
  drainage basin of 217
Deseret, Utah, Sevier river supplying 227
"Desert", Oregon, soil of the 207
Devils lake, North Dakota, artesian wells at 262
Droughts in Colorado, suffering caused by 98
  Nevada, 1889 186
  Oregon, loss of crops in 1888 and 1889, by 211
Drew valley, Oregon, irrigation in 212
Dry farming, in California 61, 67, 75
  Colorado, failure of 126, 132
  Idaho, benefit of, in Oneida county 154
  Montana 173
  Utah 219
  Wyoming, the failure of 254
Duarte Mutual Irrigation and Canal Company, California 60
Duchesne river, Utah, catchment area of 233
Duckwater creek, Nevada, ditches taken from 188
Dudleyville, Ariz., San Pedro creek at 30
Duty of water in San Bernardino county, Cal 75
  in Idaho 143
  charge per second-foot 53
Durant Vigil ditch, Colorado 119
Durango, Colo., ditches near 116

E.

Page.
Eagle Lake Land and Irrigation Company, California 56
Eagle lake, California, description of 55
Eagle river, Colorado, irrigation along the 109
Eagle rock, Idaho, elevation of 145
Eagle Rock and Willow Creek Water Company canal, Idaho 146, 147
Eagle valley, Nevada, advantages of storage reservoirs in 188
Eastern Idaho Water Company, Idaho 144
East Gallatin river, Montana, canals taken from 166
East Riverside district, California 74
East Whittier Land and Water Company, California 60
Eddy county, N. Mex., taken from Lincoln county, N. Mex 198
Egyptian methods of raising water 176
El Cajon valley, California, fruit culture in 75
Elk mountains, Colorado, mining industry of 113
Elkader Water Power and Irrigation Company, Nebraska 274
Elk river, Colorado, water diverted from 130
Ellendale, N. Dak., artesian wells at 262
Ellensburg, Wash., agricultural area near 242
Ellensburg Water Company, Washington 243
Elmore County Irrigation Company, Idaho 150
El Paso, Tex., discharge of Rio Grande at 197
  irrigation at 278
El Rito creek, New Mexico, water supply of 199
Elsinore district, California 77
Embudo, N. Mex., discharge of Rio Grande at 199
Emele ditch, Oregon, taken from Powder river 217
Embudo creek, New Mexico, ditches taken from 201
Empire canal, Colorado 129
Empire ditch, Nebraska, length and cost of 269
Empire, Nev., water utilized by mill owners at 187
Emmett, Idaho, canals in the vicinity of 140
English walnuts in Orange county, Cal 65
Enterprise ditch, Nebraska 268
Enterprise canal, California, taken from Kings river 47
Escalante river, Utah, tilled land along the head waters of 226
Escondido district, California 77
Espanola valley, New Mexico, irrigated land of 194, 199
Essex, Nev., discharge of Truckee river at 190
Etiwanda Water Company, California 74
Eucalyptus or Australian blue gum, cultivated without artificial watering in California 75
Eureka, Nev., irrigation in the vicinity of 192
Eureka flats, Washington, the extent of 245
Evaporation in California, measurement of 51
  disappearance of rivers by 182, 185
Excelsior Water and Mining Company, California 89
Excelsior Canal Company, Montana 168

F.

Fallbrook district, California 77
Fallow land in Utah, cultivation, alternate years of 230
Fall River valley, California, irrigation in 81
Falls river in canyon, Idaho, discharge of 145
Farms, defined 1
  total number of 1, 3
  size of irrigated 1, 7
    Arizona, number and value of 22
    California, number and value of 33
    Colorado, number and value of 90
    Idaho, number and value of 136
    Montana, number and value of 157
    Nevada, number and value of 177
    New Mexico, number and value of 193
    Utah, number and value of 218
    Washington, number and value of 236
    Wyoming, number and value of 248
Farming in Colorado, without irrigation 97
Farmers canal, Arizona 28
  ditch, California 81
  Union ditch, Colorado 129
  ditch, Idaho, water taken from Weiser river 155
  Friend ditch, Idaho, length and cost of 146, 147
  canal, Nebraska 267
  ditch, Oregon, taken from Eagle creek 217
Feather river, ditches and flumes taken from 42
Feather River valley, California, wells in 67
Feliz river, New Mexico, canals taken from 198
Field committee in Utah, regulation of water during crop season, by 227
Finkle, F. C., report of East Riverside district, by 74
Fish creek, Oregon, use as canal of 217

Page.
Fish lake, Utah, use of, as reservoir 228
Flagstaff, Ariz., elevation of 31
Flathead Indian reservation, Mont 173
Flint Creek valley, Montana, mining and stock raising of 165
Flood water available in Colorado 93
Flooding, applying water by 20, 23, 125
Floods, channels excavated by 227
Florence, Ariz., canals in the vicinity of 31
  Colo., oil wells at 99
Florida Ditch Company, Colorado 116
Florida mesa ditch, Colorado 116
Florida River valley, Colorado, agricultural lands in 116
Flotation lateral, Idaho 141
Flowing water, value to each acre of 13
Flowing wells in California 67, 79, 81, 82
Fluctuation of rainfall 13
Flumes, wooden 20
Folsom Water Power Company, California 68
Foote, Mr. A. D., discharge of Boise river, by 141
Fort Bidwell, Cal., flowing wells at 64
Fort Collins, Colo., agricultural experiment station at 95
  discharge of Cache la Poudre river at 117
  conditions for irrigation near 96
Fort Hall Indian reservation, Idaho 144, 153
Fort Klamath, Ore., mean annual rainfall at 204
Fort Laramie, Wyo., irrigation in vicinity of 254
Fort Lyon, Colo., failure to find artesian water at 99
Fort Wingate, N. Mex., flowing well at 195
Fountain creek, Colorado, underflow on 110, 127
Fowler Switch canal, California 49
Franceville, Colo., deep borings at 110
Fremont river, Utah, drainage basin of 228
French canal, Arizona 28
Frenchman creek, Nebraska, discharge of 271, 272
  river, Colorado, water supply of 125
Fresno Canal and Irrigation Company, California 48
Fresno creek, California, discharge of 46
Frio river, Texas, ditches taken from 281
Fruit culture in California 40, 65, 68, 89
  without irrigation 67
Fruit trees, method of irrigating 20
Furrows, irrigating by 20

G.

Gage canal, California 72
Galena creek, Nevada, water supply of 189
Gallatin Canal Company, Montana 168
Gallatin valley, Montana, agriculture in 166
Gallaway ditch, Washington, taken from Wilson creek 242
Gannett, Henry, estimates of water supply, by 130
Garden City canal, Kansas 176
Garden Grove, flowing wells in vicinity of 66
Garden valley, Idaho, irrigated areas of 148
Geological conditions favoring artesian wells 17
Georgetown, Colo., altitude of 105
Gentile valley, Idaho, described 144
Gering, Neb., irrigation in the vicinity of 268
Gila River valley, New Mexico, pasturage of 201
Gila River basin, Arizona, high plateaus of 22
Gila river at Buttes, Arizona 25, 30, 32, 288
Gila Bend Reservoir and Irrigation Company, Arizona 29
Gilbert, G. K., explanation of the nonsaline character of Oregon lakes 208
Glendora District and Waterworks, California 60
Glenn county, Cal 43
Glenrose, Tex., artesian wells in the vicinity of 279
Glenwood, Colo., canals in the vicinity of 112, 113
Golden, Colo., gauging on Clear creek at 114
Golden city and Ralston ditch, Colorado 115
Gooding ditch, Nevada 188
Goose creek, Wyoming, adaptability for irrigation of 255
  Idaho, measurement of 148
Goose lake, California, described 64
  Oregon, agricultural settlements in vicinity of 211, 212
Goose slough, California 53
Gothenburg canal, Nebraska, used for water power 270
Graham ditch, Arizona, described 26
Grand canal, Arizona, described 28
Grand coulee, Washington, described 241
Grand Junction, Colo., canals in vicinity of 121
Grand mesa, Colorado, water supply of 108
Grand river, Colorado, water supply of 112, 296

Page.
Grand river and Roaring Fork canal, Colorado 113
Grand Ronde, Oregon, drainage basin of 216
Grand Ronde valley, Oregon, stock raising in 240
Grand Valley canal, Colorado 121
Granite creek, Arizona, feasibility of storage water along 32
Grasshopper creek, Montana, water supply of 162
Grasshopper, in Idaho, ravages of 152
Grayson county, Tex., wells in 282
Grazing in California, value of 55
Great basin, Nevada, described 177, 178
Great Western canal, Idaho 146
Greeley, Colo., deep wells at 98
Greely, Gen. A. W., report on distribution of rainfall 14
  the climate of Oregon 203
Green river, Wyoming, irrigable land along the 252
  limited irrigation along 255
Green River valley, Utah, elevation of tilled land in 226
Greenville, Utah, altitute of agricultural lands in vicinity of 222
Grey Bull river, Wyoming, water supply of 253
Griffin canal, Arizona 28
Gunnison river, Colorado, value in irrigation of 108, 296

H.

Hagerman canal, New Mexico, described 198
Hagin and Carr, land of, in California 50
Haigler Land and Canal Company, Nebraska, water taken from the Republican river 272
Hailey, Idaho, Wood river measured near 152
Hamptonville, Cal., discharge of San Joaquin river at 47
Harney valley, Oregon, areas flooded in 209
Hartland, Kan., irrigation in vicinity of 275
Hassayampa river, Arizona, head waters of 28, 32
Hayden, Colo., reservoir sites near 116
Hayden survey, river measurements by 121, 125
"Head" in irrigation, use of 59
Helena, Mont., water raised by windmills at 161
Henry Fork, Idaho, discharge of 145
Herndon, Cal., discharge of San Joaquin river at 46
Hesperia Land and Water Company, California 74
Highland ditch, Colorado 103
  Nevada, described 191
"High Line" canal, Colorado, description of 101
High Water ditches, Montana, storage by 176
High Wood mountains, Montana, water supply of 164
Hiko spring, Nevada, water supply of 157
Hill, R. T., geologic structure of Texas, and artesian conditions, described by 282
Hobble creek, Utah, water supply of 232
Hollingsworth ditch, Nebraska, used for flood waters 270
Holt, L. M., report by, on irrigation districts 39
Home Supply Company ditch, Colorado, described 119
Hondo river, New Mexico, ditches taken from 198
Honey lake, California, description of 55
Honey Lake Land and Irrigation Company, California 56
Hood river, Oregon, irrigation along 217
Hood River valley, Oregon, small ditches in 217
Horr, Mont., Yellowstone river at 173
Horse creek, Colorado, limited supply of water of 102
Horse Heaven plateau, Washington, failure to find artesian water at 247
Horse power, pumping in California by 68
Horse Prairie creek, Montana, water supply of 162
Hougham and Howard ditch, Nevada 188
Houston Flat, Cal., capacity of reservoir at 74
Huerfano river, Colorado, measurement of 127
Humboldt lake, Nevada, described 185
Humboldt river, Nevada, evaporation of 185, 186, 299
Humboldt (Little), Nevada, drainage of 185
Hyde Park and Smithfield canal, Utah 225
Hydrant water, use and cost for irrigation of 58
Hydraulic mining in California, cessation of 89

I.

Ibapah, Utah, agricultural land in vicinity of 233
Idaho canal, Idaho 146
Idaho—counties of:
  Ada 140, 141
  Alturas 141, 142
  Bear Lake 142, 143
  Bingham .... [illegible], 144, 145, 146, 147
  Boise 148

Idaho, counties of—Continued. Page.
- Cassia 148, 149
- Custer 149
- Elmore 149, 150
- Idaho 150
- Kootenai 150, 151
- Latah 151
- Lemhi 151
- Logan 151, 152
- Nez Perces 152, 153
- Oneida 153, 154
- Owyhee 154, 155
- Shoshone 155
- Washington 155, 156

Idaho Falls, Idaho, irrigation near 144, 145
Iliff and Platte Valley canal, Colorado, description of 120
Illinois river, Oregon, drainage basin of 210
"Inch" of water defined 12, 148
Increase in values of irrigated land 10
Indian Valley and Gray Creek ditch, Idaho 156
Indian valley, Idaho, water supply of 156
Indio, Cal., depth of water at 77
Investment in irrigation works and lands cultivated 9
Investigations, by California state officials 37
Inyan Kara, Wyoming, difficulty of taking ditches from 252
Inyo canal, California, described 49
Ironstone ditch, Colorado, described 108
Irrigated land, value of 8
Irrigating season, length of 139, 154
"Irrigating streams" defined 143
Irrigation canals and ditches, expense of construction of 11
- ditches, cost of 181
- districts, in California 34, 37
- first cost of 10
- methods by states:
  - San Bernardino county, Cal 75
  - Colorado, advantages of 96
  - Idaho, necessity of 138
  - Montana, development of 159
  - New Mexico, Rio Grande valley 196
  - Oregon, legislation 204
  - Utah, day and night 225
  - Washington 236
- natural meadows 131
- small furrows for 185
- systems, value of 10

Irrigators, number of 1

J.

Jack county, Tex., mineral water in 282
Jackson county, Ore., irrigation in 203
Jamacha district, California, described 77
James, Walter, description of Kern County Land Company's works 52-54
James river valley, North Dakota, artesian wells in 261
Jamestown, N. Dak., artesian wells at 262
Jefferson ditch, Montana, described 168
Jerusalem creek, Idaho, small ditches taken from 148
Johnday river, water supply of 207, 208
Jones creek, North Dakota, ditches taken from 260
Jordan creek, Idaho, agricultural lands along 155
Jordan valley, Oregon, ranches in 213
Jordan River valley, Utah, facilities for irrigation in 229
Josephine county, Ore., irrigation in 203
Judith river, Montana, ditches taken from 165, 168
Julesburg, Colo., South Platte river at 270

K.

Kanab creek, Utah, water supply of 227
Kansas canal, Kansas, covering lands in the vicinity of Garden city, Kan. 276
Kansas—counties of:
- Cheyenne 273
- Clark 276
- Decatur 273
- Finney 274
- Ford 274
- Garfield 274
- Grove 274
- Graham 273
- Grant 276
- Gray 274
- Greeley 274

Kansas, counties of—Continued. Page.
- Hamilton 274
- Haskell 276
- Hodgeman 274
- Kearny 274
- Lane 274
- Logan 274
- Meade 276
- Morton 276
- Ness 274
- Norton 273
- Rawlins 273
- Scott 274
- Seward 276
- Sheridan 273
- Sherman 273
- Stanton 276
- Stevens 276
- Thomas 273
- Trego 274
- Wallace 274
- Wichita 274

Kansas Waterwork and Irrigation Company, Kansas, described 276
Kaweah Canal and Irrigation Company, California 87
Kaweah river, discharge of 84, 85
Kearney canal, Nebraska, used to furnish power 270, 271
Kendall, Kan., proposed canals in the vicinity of 275
Kennedy, J. C., conditions of irrigation in Colorado, by 130
Kerby, Ore., irrigation in vicinity of 210
Kern county, Cal., artesian wells of 50
Kern County Land Company, California 50
Kern lake, California, evaporation from 52
Kern river, California, discharge of 51, 292, 293
Kimball, Neb., canals in vicinity of 269
King river, Nevada, water supply of 185, 186
Kings river, California, discharge of 46, 47, 84
Kings river and Fresno canal, California 48
Kiona, Wash., canals in vicinity of 247
Kit Carson Colo., deep well at 99
Kittitas valley, Washington, description of 246
Klamath Falls Irrigation Company, Oregon, described 211
Klamath lakes, Oregon, utilization in irrigation 211
Klamath river, Oregon, drainage basin of 81, 210
Kootenai river, Montana irrigation in the valley of 172
Kraft irrigation district, California 44, 45

L.

La Belle canal, Idaho, gaugings of 147
Lahontan lake, described 178, 189
Laird, Colo. ditches in vicinity of 135
Lajoya, N. Mex., irrigated land in vicinity of 199
Lajunta, Colo., discharge of Arkansas river at 123
Lakeside canal, California, described 87
Lake fork, Colorado, measurements of discharge of 115
Lake Tahoe, Nevada, utilization as a reservoir of 189
Laketown, Utah, irrigated farms in vicinity of 220
Lamar Land and Canal Company's ditch, Colorado 126
Land, value of irrigated 5
La Plata river, Colorado, agricultural area along 116
Laramie plains, Wyoming, water supply of 251
Laramie range, agricultural land along creeks from 254
Laramie river, Colorado, storage water of 116
- Wyoming, canals taken from 254, 305

Laramie and Scotts Bluff canal, Nebraska 268
Larimer and Weld canal, Colorado 135
La Sal mountains, Utah, water supply of 226
Las Animas river, Colorado, agricultural areas along 116
- discharge at Las Animas, of 102

Last Chance ditch, Idaho, described 140
- Colorado, described 113, 134

Las Vegas, N. Mex., deep well in vicinity of 195
Laterals, watering by 106
Laurin, Mont., discharge of Ruby river at 171
Laws, Colorado, irrigation 94
- Wyoming 236

Leadville, Colo., gaugings near 115
Leamington, Utah, Sevier river at 228
Leffel turbine, elevating water by 61
Leland creek, Oregon, drainage basin of 210
Lemhi river, Idaho, irrigation from the 151
Lemon valley, Nevada, wells and water supply 189
Levees for irrigation, description of 61

Page.
Lewiston, Idaho, orchards at ... 153
Lewiston Mining, Milling and Irrigating ditch, Idaho ... 153
Lewisville canal, Idaho, gaugings of ... 147
Llano Estacado, N. Mex., water supply of ... 198
Lincoln ditch, Colorado, described ... 110
Linda Vista district, California ... 77
Linkville, Ore., irrigation canals in vicinity of ... 211
Litigation, caused by crude laws ... 149
Little Bear Creek ditch, Colorado ... 130
Little Bear Valley, California, reservoir in ... 74
Little Colorado river, Arizona, ditches from ... 24
Little Giant ditch, South Dakota, described ... 264
Little Klamath ditch, Oregon, water taken from ... 211
Little Lost river, Idaho, catchment basin of ... 141, 149
Little Missouri river, Montana, water supply of ... 164
Little Rock creek, California, canals from ... 60
Lock ditch, Colorado, water from Fountain creek ... 110
Lodge Pole creek, Wyoming, water for irrigation ... 254
Lodge Pole creek, Nebraska, ditches from ... 269
Logan and Benson canal, Utah, described ... 225
Logan and Hyde Park canal, Utah, described ... 225
Logan and Richmond canal, Utah, described ... 225
Lonetree ditch, South Dakota, described ... 264
Longmont, Colo., wells at ... 99
Long Valley creek, California, discharge of ... 56
Long Valley, Idaho, agricultural lands in ... 148
Los Angeles river, California, importance for irrigation from ... 57, 58
Los Pinos ditch, Colorado, described ... 106
Lost river, Oregon, opportunity for irrigation from ... 210, 211
Louden canal, Colorado, described ... 118
Loup river, Nebraska, canals, from ... 271, 308
Loveland and Greeley canal, Colorado, described ... 119
Lovelocks, Nev., water at ... 180
Lower Boulder ditch, Colorado, described ... 134
Lower Payette ditch, Idaho, described ... 140
Low Line ditch, Colorado, described ... 120
Lytle creek, California, discharge of ... 70, 74

M.

Madeline plains, California, described ... 55
Madera canal, California, described ... 49
Madison river, Montana, ditches from ... 168
  discharge of ... 170, 171, 298
Maggie creek, Nevada, reservoir sites on ... 184
Major-domo, control of water by ... 107
Malade river, Idaho, water supply of ... 151, 153
  Utah, saline water of ... 223
Malade valley, Utah, dry farming in ... 223
Malheur lake, utilization as storage reservoir ... 209
Malheur river, discharge at Vale, Ore., of ... 214, 302
Mann creek, Idaho, ditch from ... 156
Mancos river, Colorado, ditches from ... 122
Marias river, Montana, ditches from ... 164, 172
Maricopa canal, Arizona, described ... 28
Marienfield, Texas, fruit culture in vicinity of ... 280
Mariposa creek, California, discharge of ... 62
Market lake, Idaho, irrigation in vicinity of ... 144
Marsh creek, Idaho, agricultural areas along ... 144
Martin creek, Nevada, ditches from ... 186
Martindale, Mont., discharge of Musselshell at ... 172
Mary river, Nevada, reservoir sites on ... 184
Marysville, Cal., deep wells at ... 83
Mason valley, Nevada, described ... 187
Maxwell creek, California, ditches from ... 61
Maxwell, N. Mex., irrigating systems in vicinity of ... 196
McCook, Neb., canals in vicinity of ... 272
McKaye creek, Oregon, favorable reservoir sites on ... 216
McLellan ditch, Arizona, described ... 31
Mecitos ditch, Colorado, described ... 106
Medicine Bow mountains, Wyoming, streams from ... 251
Meeker ditch, Nebraska, described ... 272
Medicine Lodge creek, Idaho, ditches from ... 151
Merced canal, California, described ... 63
Merced river, discharge of ... 62
Mesa canal, Arizona, described ... 29
Mesilla valley, New Mexico, irrigation in ... 197
Mexican farms, size of ... 107, 194
Mexican methods of irrigation ... 107, 195
Middle Valley irrigation ditch, Idaho, described ... 156
Middle park, Colorado, described ... 113
Miles City ditch, Montana, described ... 164
Milk river, Montana, irrigation in the valley of ... 163, 261
Miller ditch, Colorado, described ... 106
Mills, water for ... 165
Mimbres river, New Mexico, underflow of ... 196
Minam River valley, Oregon, irrigation not necessary in ... 216
Minatare canal, Nebraska, described ... 268
Miner's inch, defined ... 12
  per day, cost of ... 42, 43, 45, 65, 89
Minersville, Utah, agricultural lands in vicinity of ... 222
Minnesela, S. Dak., irrigation in vicinity of ... 264
Minnesota and Montana Land and Improvement Company's canal, Montana ... 176
Missouri Park ditch, Colorado, described ... 104
Missouri river, discharge of ... 169, 170, 298
  ditches in North Dakota from ... 261
Missouri River valley, Montana, water supply of ... 172
Mitchell canal, Nebraska, described ... 268
Moab, Utah, agricultural lands in the vicinity of ... 226
Moapa, Nev., irrigation in the vicinity of ... 187
Modesto, Cal., discharge of Tuolumne river at ... 82
Modesto district, California, described ... 83
Mogote ditch, Colorado, described ... 106
Mohave, Cal., proposed reservoir on Oak creek, near ... 55
Mohave river, California, canals from ... 74, 291
Mokelumne river, California, discharge of ... 79, 292
Montana, counties of:
  Beaverhead ... 161, 163
  Cascade ... 162, 163
  Choteau ... 163, 164
  Custer ... 164
  Dawson ... 165
  Deerlodge ... 165
  Fergus ... 165, 166
  Gallatin ... 166, 167, 168
  Jefferson ... 168
  Lewis and Clarke ... 168, 169
  Madison ... 170, 171
  Meagher ... 171, 172
  Missoula ... 172, 173
  Park ... 173, 174, 175
  Silverbow ... 175
  Yellowstone ... 175, 176
Monte Vista Canal Company, Colorado ... 129
Montevista, Colo., flowing wells at ... 100
Montezuma canal, Arizona, described ... 26
Montrose Canal Company, Colorado ... 122
Montrose, Colo., discharge of Uncompaghre river at ... 122
Monument creek, water supply of ... 110
Mora, N. Mex., deep wells in vicinity of ... 195
Mora river, New Mexico, water supply of ... 199, 301
Morrison, Colo., measurements of Bear creek at ... 114
Mormon canyon, California, storage reservoir of ... 58
Moscow, Wash., flowing wells at ... 245
Moses coulee, Washington, described ... 241
Mountain Home, Idaho, water supply of ... 150
Mount Defiance, Oregon, irrigation from springs ... 217
Mount Hood, Oregon, altitude of ... 203
Mount Shasta, forage crops without irrigation in the vicinity of ... 81
Mouse River valley, North Dakota, practicability of diverting water to ... 261
Moxee valley, Washington, artesian wells in ... 247
Muddy river, Nevada, ranches in vicinity of ... 187
Mussel slough, California, artesian wells in ... 84
Musselshell river, Montana, irrigation along ... 168, 176

N.

Naches river, Washington, perennial supply of ... 246
Nambe river, New Mexico, water supply of ... 200
Natural gas in Utah ... 221
Naturito Ditch Company, Colorado ... 131
Nevada—counties of:
  Churchill ... 182
  Douglas ... 182, 183
  Elko ... 184
  Esmeralda ... 184, 185
  Eureka ... 185
  Humboldt ... 185, 186
  Lander ... 186
  Lincoln ... 186, 187
  Lyon ... 187, 188
  Nye ... 188
  Ormsby ... 188

Page.

- Nevada, counties of—Continued.
  - Storey 189
  - Washoe 189, 190, 191
  - White Pine 192
- Newark valley, Nevada, agricultural land in 192
- New Fork, Wyoming, difficulty of irrigating from 253
- New Mexico—counties of:
  - Bernalillo 196
  - Colfax 196, 197
  - Donna Ana 197
  - Grant 197, 198
  - Lincoln 198
  - Mora 198
  - Rio Arriba 199
  - San Miguel 200
  - Santa Fe 200
  - Sierra 200
  - Socorro 201
  - Taos 201
  - Valencia 201
- Newton, Utah, reservoir at 224
- Nez Perces Indian reservation, described 150, 152
- Niobrara river, Nebraska, water supply of 269
- Noria, Egyptian method of raising water by 142, 176, 240
- Northern Colorado Irrigating Company, Colorado 101, 109
- Northern Pacific, Yakima and Kittitas Irrigation Company, Washington 247
- Northern transcontinental survey, maps prepared by 244
- North Fork Farmers ditch, Colorado 108
- North Loup river, Nebraska, water supply of 269
- North Park, Colorado, described 116
- North Platte canal, Nebraska, length and cost of 270
- North Platte river, Nebraska, water supply of 267, 308
- North Poudre canal, Colorado, described 118
- North Side Irrigating and Milling Company ditch, Nebraska 269
- North Truckee ditch, Nevada, described 191
- Nueces river, Texas, ditches from 281
- Nutrias creek, New Mexico, water supply of 199

O.

- Oak creek, California, irrigation from 55
- Oakdale, Cal., discharge of Stanislaus river at 83
- Oasis, Utah, water supply at 227
- Oats, production by states:
  - Arizona 22
  - California 33
  - Colorado 90
  - Idaho 136
  - Montana 157
  - Nevada 177
  - New Mexico 193
  - Oregon 202
  - Utah 218
  - Washington 236
  - Wyoming 248
- Ogallala, Neb., canals in vicinity of 270
- Ogden river, Utah, discharge of 235, 304
- Old Channel canal, Idaho, measurements of 147
- Oligarchy ditch, Colorado, described 104
- Orchard Irrigation Company, Idaho, described 150
- Oregon—counties of:
  - Baker 206
  - Crook 207
  - Gilliam 207
  - Grant 207, 208
  - Harney 208, 209
  - Jackson 209, 210
  - Josephine 210
  - Klamath 210, 211
  - Lake 211, 212
  - Malheur 213, 214
  - Morrow 214, 215
  - Sherman 215
  - Umatilla 215, 216
  - Union 216, 217
  - Wallowa 217
  - Wasco 217
- Oregon, number of farms in 202
  - precipitation in 203
  - topography of 202
  - water supply of 203
- Oroville, Cal., deep well at 42
- Orr ditch, Nevada, described 191
- Otero canal, Colorado, described 124

Page.

- Otter creek, Utah, reservoir sites on 229
- Overton, Nev., irrigation in the vicinity of 187
- Owens river, California, described 49
- Owl creek, irrigation on 253
- Owyhee Land and Irrigation Company, Oregon 155
- Owyhee river, Idaho, agriculture along 155
  - Oregon, discharge at Rigsby of 214, 215, 302
- Oxford Farmers ditch, Colorado, described 124

P.

- Pagosa Springs, Colo., survey for ditches at 102
- Pahranagat valley, Nevada, water supply of 187
- Pahsimeroi valley, Idaho, agriculture in 149
- Paisley, Ore., agricultural settlements in vicinity of 211
- Paladora creek, Kansas, ditches taken from 277
- Palermo Land and Water Company, California, described 42
- Palmdale Irrigation Company, California, described 60
- Panama slough, California, evaporation from 52
- Parachute, Colo., agriculture in the vicinity of 112
- Paradise, Utah, canals in the vicinity of 225
- Paradise valley, Nevada, irrigation in 186
- Paria river, Utah, land along the head waters of 226
- Park reservoir, Colorado, description of 108
- Pasco, Wash., proposed canal from the Snake river at 241
- Pawnee Land and Cattle Company canal, Colorado 120
- Payette river, Idaho, irrigation from the 140, 297
  - north fork of 148
- Payette Valley Irrigation and Water Power Company, Idaho 140
- Pecos Irrigation and Improvement Company, New Mexico 198
- Pecos river, New Mexico, canals from 198, 200, 279
  - drainage basin of 198
- Pechastin river, Washington, ditches from 242
- Pendleton, Ore., Umatilla river at 216
- Peoples ditch, California, described 86
- Perris district, California, described 72, 74, 77
- Phenix, Ariz., canals in the vicinity of 26, 28, 288
- Piceance Creek valley, Colorado, arable land in 127
- Pine creek, Nevada, water supply of 185
- Pioneer canal, Texas, taken from Pecos river 279
- Pipes, irrigation by 19, 21, 66
- Pioche, Nev., average rainfall at 187
- Pitt river, California, irrigation on 55, 56, 63, 64, 80
- Placer mining, Oregon, importance of 206
- Platte Valley canal, Colorado, described 133
- Pleasant Valley ditch, Colorado, described 130
- Pleasant Valley, Idaho, described 155
- Pleasant Valley and Lake canal, Colorado 118
- Plum creek, Colorado, canals from 109
- Pocatello, Idaho, land in the vicinity of 144
- Pomona Orange Belt district, California 60
- Pool irrigation in New Mexico 196
- Pools, water distributed by 23
- Population by states and territories:
  - Arizona 22
  - California 33
  - Colorado 90
  - Idaho 136
  - Kansas, decrease of in western 258
  - Montana 157
  - Nevada 177
  - New Mexico 193
  - Oregon 202
  - Utah 218
  - Washington 236
  - Wyoming 248
- Porter ditches, Nebraska, described 272
- Portneuf range, Idaho, water supply of 144
- Poso creek, California, discharge of 51
- Powder river, Oregon, ditches from 216
  - Wyoming, water supply of 255
- Powell park, Colorado, water supply of 127
- Precipitation, average 14
  - distribution in Colorado of 93
  - in Oregon 203
  - in Washington 237
- Prescott, Ariz., irrigation at 31
- Pressure in wells, decrease of 100
  - used for power 265
- Prickly Pear valley, Montana, fertility of the 169
- Priest rapids, Washington, proposed canal from 241
- Prineville Irrigation Company, Oregon, described 207
- Prior appropriation of water 186

Page.
Priorities of right, defined 94, 114, 219
Products, average value of 1
Prosser creek, Nevada, discharge of 189
Prosser, Wash., canals in vicinity of 247
Provo river, discharge above Provo, Utah 232, 233, 303
Pueblo, Colo., discharge of Arkansas river at 126
Pueblo, Colo., deep wells at 99
Pulsometers, raising water by 240, 241
Pullman, Wash., wells in vicinity of 245
Pumping plant, cost of 240
Pumpkinseed creek, Nebraska, ditches from 269
Pump, Greeley vacuum 133
Pumps, steam 104
Purgatory river, Colorado, water supply of 102, 103, 119, 123

Q.

Quinn river, Nevada, water supply of 185

R.

Raft river, Idaho, canal construction from 148
"Rain belters", unsuccessful 132
Rainfall, annual 13
Rainfall, in Arizona 23
  California 35
  Colorado 91, 92
  Idaho 137
  Montana 158
  Nevada 180
  of the plains region 238, 258, 260
Raisin culture in California 40, 74
Ralston desert, Nevada, described 188
Rapid creek, South Dakota, ditches from 264
Rattlesnake creek, Idaho, dams on 150
  range, Wyoming, creeks from 254
Redbluff, Mont., discharge of Madison at 170, 171
Red fork of Colorado river, Texas, diverting water from 279
Red river, New Mexico, canals from 196
Red River of the North, North Dakota, flowing wells in the vicinity of the 261, 262
Redrock creek, Montana, water supply of 162
Redwater creek, South Dakota, ditches from 264
Reeder lake, California, evaporation of 52
Reese River valley, advantage of reservoirs in 188
Reese valley, Nevada, wells in 186
Reid ditch, Colorado, described 130
Relief ditch, Colorado, described 108
Reno, Nev., tilled land in vicinity of 189
Rent, of water rights 233
Republican ditch, Montana 172
  river, Colorado, irrigation along the 115
    water supply of 271, 308
Reservoirs for artesian water 17
  in Colorado 93, 117, 121, 130
Reservoir sites, in Idaho 142, 152
  Montana 165
  Nevada, in Humboldt valley 184
Reservoirs in New Mexico, successful operation of 198
  in Utah, small storage 231
  for storage 19
Reservoir, Utah lake as a natural 229
Rialto district, California, described 75
Rico, Colo., agricultural area in vicinity of 108
Ridenbaugh ditch, Idaho, described 141
Rigsby, Ore., Owyhee river at 214, 215
Rillito creek, Arizona, canal from 30
Rio Grande, discharge at Del Norte, Colo 128, 296
    El Paso, Tex 197, 302
    Embudo, N. Mex 199, 302
  in Colorado, diversion of water from 107
  in New Mexico, diversion of water from 194, 196
  in Texas, irrigation from 278
Rio Puerco river, New Mexico, small ditches from 201
Riverside irrigating system, California, described 73
Roaring fork, Colorado, centrifugal force pumps on 113
Rocca ditch, California, described 55
Rock creek, Idaho, irrigated areas along 153
  Montana, water supply of 173
Rockyford Town ditch, Colorado, described 124
  High Line canal, Colorado, described 124
Rogue river, Oregon, irrigation from 210
Rosebud River valley, Montana, water supply of 164
Roswell, N. Mex., irrigation in vicinity of 198

Page.
Round valley, Idaho, water supply of 149
Ruby mountains, Nevada, cultivation of land at base of 184
Ruby Valley ditch, Montana, described 171
Run, or head, use of 60
Russell, I. C., reports on reservoirs and artesian conditions in Washington 239, 243
  measurements of the Humboldt river, Nevada 185
Russian river, California, water supply of 61
Rye, raised without irrigation 126, 151

S.

Sacramento mountains, New Mexico, streams flowing from 198
  river, California, irrigation along 43
    discharge of 44, 292
St. Anthony canal, Idaho, described 146
St. Charles creek, Idaho, use for power 142
  river, Colorado, discharge of, near Pueblo 107, 127
St. John canal, Arizona, described 28
St. Johns, Ariz., ditches at 25
St. Vrain creek, Colorado, water supply of 103, 295
Salinas river, California, described 61
  valley, California, rainfall of 64
Salmon river, Idaho, irrigation along 149, 151
Salt creek, Utah, water supply of 232
  river, Arizona, canals from 26
  River canal, Arizona, described 28
    discharge at Arizona dam of 27, 289
San Antonio creek, California, discharge of 58
  river, Texas, ditches from 280, 313
San Bernardino and Salinas Valley canal, California, described 64
Sand, ditches filling with 135
Sandia mountains, New Mexico, water supply from 196
San Diego flume, California, described 76
  river, California, water supply from 76, 77
San Felipe creek, Texas, ditches from 281
San Fernando valley, California, described 57
San Francisco canal, Arizona, described 28
  river, New Mexico, headwaters of 201
San Gabriel, Cal., flowing wells at 59
  river, California, importance in irrigation 57, 58, 294
  valley, California, described 57
San Ildefonso, N. Mex., irrigation in the vicinity of 199, 200
San Jacinto, California, discharge of 76
  valley, California, artesian wells and canals in 77
San Joaquin and Kings River Canal and Irrigation Company, California, described 63, 82
  river, California, discharge of 47, 292
  valley, California, soil of 46
San Jose, Cal., artesian wells in the vicinity of 80
  river, New Mexico, irrigation from 201
San Juan, Utah, expense of taking canals from 230
  river, New Mexico, head waters of 199, 200, 297
San Luis Rey river, California, watershed of 76, 291
  valley, Colorado, artesian basin of 99
    irrigating canals in 127
San Miguel, Colorado, ditches along the 131
San Pedro creek, Arizona, canal from 30
    discharge at Dudleyville of 30, 31
  and tributaries, Arizona, water supply of 250
Sanpitch valley, Utah, control of the water supply of 230
Santa Ana river, California, discharge of 70, 290
    irrigation along 65, 66
Santa Ana Valley Irrigation Company, California 66
Santa Clara river, California, ditches from 88
Santa Cruz river, Arizona, limited supply of water 29
Santa Fe, N. Mex., wells in vicinity of 195
Santa Gertrudes district, California, described 60
Santa Inez mountains, California, agricultural lands in the vicinity of 79
Santa Lucia mountains, California, agriculture without irrigation near 64
Santa Margarita or Temecula, California, discharge of 76
Santa Rosa mountains, Nevada, water supply from 186
Santiago creek, California, water supply of 66
Sapello river, New Mexico, drainage system of 200
Saunders canal, Arizona, described 32
Scandinavian ditch, Colorado, described 106
Scott River, California, ditches from 81
Second-foot of water defined 12
Secondary rights of water 219
Sediment in canals 197, 206
Seepage along Arkansas river 123
  crops raised by 180
  irrigation by 225

Page.
Selah valley, Washington, water supply of 246
Semi-Tropic Land and Water Company, California, described 74
Serrano and Carpenter Water Company canal, California, described 66
Sespe Land and Water Company canal, California, described 88
Settlers canal, Idaho, described 141
Sevier river, discharge at Leamington, Utah, of 228
Utah, ditches from 227, 231
Sheep creek, Oregon, ditches from 217
Sheridan, Colo., failure to find water at 99
Sierra Blanca mountains, New Mexico, streams flowing from 198
Sierra valley, California, wells in 81
Silverbow valley, Montana, described 175
Silver creek, Oregon, water supply of 209
Idaho, discharge of 152
Silver lake, Oregon, ranches in vicinity of 211, 212
Silvies river, Oregon, limited irrigation of 208, 209
Size of farms 6
Smith Creek valley, Nevada, wells in 188
Smith fork, Idaho, water from 143
Smith river, Montana, water supply of 162, 171, 172
Smith valley, Nevada, described 187
Snake river, Idaho, water supply of 144, 148, 297
discharge at Idaho Falls of 146
Washington, ditches from 240, 252
valley, Oregon, described 213
Snow, as indication of water supply 154
Snowflake, Ariz., agricultural lands in vicinity of 25
Soda springs, Idaho, irrigation in the vicinity of 142
Sonoita river, Arizona, water supply of 29
South Feather Water Company, California, ditch owned by 43
South Loup river, Nebraska, water supply of 269
South park, Colorado, described 125
South Platte river, described 97, 114, 125, 267
discharge of 270, 295
Colorado, water supply of 109, 114, 120
South Riverside system, California, described 79
South Side canal, California, described 87
Nevada, described 191
South Spring river, New Mexico, canals from 198
Southwestern canal, Kansas, from Arkansas river 276
South Yuba Water Company, California, described 67
Spanish Fork, discharge of, in Utah 232, 234
Spanish Springs valley, Nevada, need of water in 189
Spokane, Wash., agricultural interests near 150, 244
Spokane River valley, Washington, rainfall in 244
Sprague river, Oregon, water supply of 210, 211
Springer, N. Mex., irrigation system in vicinity of 196
wells in vicinity of 195
Springs and wells in Idaho 139, 150
Springs in Nevada 189
of the subhumid region 259
Spring Valley Water Company, California 41
Squaw creek, Idaho, irrigation along 148
Stanislaus river, discharge 78, 83, 292, 293
State canal at Canyon City, Colo 110
State supervision of irrigation in Colorado 94
Wyoming 250
Steamboat ditch, Nevada, described 191
Steamboat springs, Colorado, cereals raised without irrigation 129
Steam pumps in California, raising water by 68
Sterling ditch, Colorado, described 120
Stillwater creek, California, water supply of 80
Stock raising as an important industry 130, 136, 168
Stock in California, rental per acre for 55
Storage facilities of Bear lake for 153
Storage reservoirs in Oregon for flood water 204
Nevada, at head waters of Carson and Truckee 179
New Mexico, of Pecos river 198
Storage sites in Montana 169, 175
Storm waters, irrigation in the subhumid states with 259
Subhumid defined 1
states, farms in 2
Subhumid states:
Kansas 273–277, 309
Nebraska 266–272, 307
North Dakota 260–262, 307
South Dakota 263–265, 307
Texas 278–283, 312
Subirrigation defined 106
in Idaho, practice of 152
Sullivan ditch, Nevada, described 191
Sulphur spring, Arizona, valley of 25

Page.
Summit, California, precipitation at 180
Summer lake, Oregon, described 208
Sun river, discharge above Augusta, Mont 162
ditch, Montana, described 163
Montana, the amount of water available from 162
Sunset district, California, described 87
Surface creek, Colorado, supply of water from 108
Surprise valley, California, lakes of 60
Susan river, California, water supply of 56
Susie creek, Nevada, reservoir sites on 184
Swan lake, Idaho, settlements in the vicinity of 44
Sweetwater reservoir, California, discharge of 76, 291
Swiss ditch, Arizona, described 31
Sybille creek, Wyoming, water supply of 254
Syracuse, Kan., canals in vicinity of 274, 275

T.

Tahoe lake, Nevada, as a natural reservoir 179
Tailings, the filling of ditches with 175
Taos creek, New Mexico, ditches from 201
Taylor, Ariz., agricultural land in vicinity of 25
Teanaway river, Washington, ditches from 243
Tempe canal, Arizona, described 28, 29
Temperature of artesian water 17
Tennessee fork, Colorado, water supply of 115
Teton river, Idaho, discharge of 146
Montana, irrigation along 164
Terrace irrigation 20
Texas—counties of:
Bell 280
Blanco 283
Brown 279
Burnet 280, 282
Coleman 279
Comanche 283
Concho 279
Coryell 280
Dimmit 281
Edwards 281
Ellis 283
Erath 283
Falls 280
Hood 283
Irion 279
Johnson 283
Kinney 281
Lampasas 279, 282
McCulloch 279
Martin 279
Maverick 281
Medina 281
Menard 279
Midland 279
Milam 280
Mills 282
Montague 282
Parker 283
San Saba 279
Somervell 283
Tom Green 279
Uvalde 281
Williamson 280
Wise 283
Zavalla 281
Texas, irrigation in 278
Thermalito canal, California, described 42, 312
Thomas Fork valley, Idaho, water supply of 143
Thousand Spring valley, Idaho, irrigation in 142
Tierra Amarilla, Chama river in vicinity of 199
Timpanogus river, Utah, water supply of 232
Timpas creek, Colorado, water supply of 119
Touchet river, Washington, area of irrigable land along 240, 245
Tongue river, Montana, discharge of 164
Tongue River valley, Wyoming, described 255
Tonto creek, Arizona, dry farming along 25
Tooele valley, Utah, mining and stock raising of 232
Toppenish, Wash., Sunnyside canal at 247
Topographic features in California, irrigation dependent upon 34
Topography of Utah 218
Toston, Mont., proposed canal from Missouri at 173
Trans-Pecos counties of Texas, irrigation in 278

Page.
Travelers Insurance Company, Grand Valley canal, Colorado ... 121
Tres Piedras, N. Mex., San Juan in vicinity of ... 190
Trinchera creek, Colo., irrigation along ... 106
Trinidad, Colo., Baca extension ditch at ... 119
Trinity river, California, ditches from ... 84
Trout creek, Nevada, water supply of ... 185
Trowbridge, jr., William P., measurements of Tuolumne river, California, by ... 82
Truckee river, Nevada, discharge at Vista, of ... 190, 191
  irrigating ditches from ... 189
Tucson, Ariz., ditches in the vicinity of ... 29
Tulare irrigation district, California ... 87
Tulare lake, California, irrigation in the vicinity of ... 84
  described ... 52
Tule lake, Oregon, irrigable land in vicinity of ... 210
Tule river, California, discharge at Porterville, of ... 86
  irrigation district described ... 87
Tunnels, development of springs by ... 225
Tuolumne County Water Company, California, described ... 88
Tuolumne river, discharge at Modesto, Cal ... 82, 83, 292, 293
Turlock district, California, described ... 83
Tuscarora, Nev., ranches in vicinity of ... 184
Twinlake creek, Colorado, water supply of ... 115
Twin lakes, Colo., irrigation in vicinity of ... 115
Twin valley, Nevada, drainage area of ... 189

U.

Uinta Indian reservation, Utah ... 233
Uinta, Utah, discharge of Weber river at ... 235
Umatilla river, water supply of ... 203, 216
Umptanum ridge, Washington, water supply from ... 246
Uncompahgre and Cedar Creek Company, Colorado, described ... 122
  river, Colorado, water supply of ... 108, 122, 296
  valley, Colorado described ... 107
Underflow from channels of South Platte ... 120
Underflow channels in Elbert county, Colo ... 109
Undershot water wheel, use in Idaho ... 142
Union canal, Arizona, described ... 26
Union Colony Canal No. 3, Colorado, described ... 124
Union ditch, Colorado, described ... 123
Uniontown, Ore., irrigation in vicinity of ... 210
United States Geological Survey, measurements by ... 55, 127, 147, 152, 287
Utah canal, Arizona, described ... 28
Utah—counties of:
  Beaver ... 223
  Boxelder ... 222, 223
  Cache ... 224, 225
  Davis ... 225, 226
  Emery ... 226
  Garfield ... 226
  Grand ... 226
  Iron ... 226
  Juab ... 227
  Kane ... 227
  Millard ... 227
  Morgan ... 228
  Piute ... 228, 229
  Rich ... 229
  Salt Lake ... 229
  San Juan ... 230
  Sanpete ... 230, 231
  Sevier ... 231
  Summit ... 231
  Tooele ... 231, 232
  Uinta ... 232
  Utah ... 232, 233
  Wasatch ... 233
  Washington ... 234
  Weber ... 234, 235
Utah lake, Utah, irrigation from ... 232
Utah valley, Utah, fertility of ... 232
Ute Indian reservation, water supply of ... 116, 232

V.

Valdez ditch, Colorado, described ... 106
Van Diest, E. C., condition of irrigation along the Culebra and Costilla rivers, Colorado ... 107
Vale, Ore., discharge of Malheur river at ... 214
Vegetables, method of irrigating ... 20
Verde river, Arizona, irrigated land along ... 32, 289
Vermejo creek, New Mexico, canals from ... 196
Vineland irrigation district, California, described ... 60
Vines, method of irrigating ... 20
Vineyards in California, destruction of ... 65
Vineland district, California, described ... 60
Virgin river, Utah, ditches from ... 227, 234
  Nevada, water supply of ... 187
Vista, Nev., discharge of Truckee at ... 190
Voluntine ditch, California, described ... 66

W.

Wabuska, Nev., canals at ... 188
Waco, Tex., deep wells at ... 283
Walker lake, Nevada, described ... 184
Walker river in California and Nevada, used for irrigation ... 64, 187, 200
Wallowa river, Oregon, ditches from ... 217
Wallawalla river, Washington, ditches from ... 240, 245
  Oregon, water supply of ... 203, 216
Walnut creek, Arizona, water supply of ... 33
Walnut Grove Water Storage Company, Arizona, described ... 32
Walters, Cal., depth of wells at ... 77
Ward and Kendrick ditch, Colorado, described ... 115
Warm Spring valley, California, irrigation in ... 64
  Oregon, irrigation in ... 217
Warner lake, Oregon, ranches in vicinity of ... 211, 212
Warner mountains, California, water supply from ... 63
Washington—counties of:
  Adams ... 240
  Asotin ... 240
  Columbia ... 240
  Douglas ... 240, 241
  Franklin ... 241
  Garfield ... 241, 242
  Kittitas ... 242, 243
  Klickitat ... 243
  Lincoln ... 243
  Spokane ... 244
  Stevens ... 244
  Wallawalla ... 245
  Whitman ... 245
  Yakima ... 246, 247
Washington ditch, California, described ... 41
Washington Irrigation Company, Washington, wells ... 247
Washoe lake, Nevada, utilized as a storage reservoir ... 189
Water commissioners of Colorado ... 94
Water, cost of hauling in Washington ... 245
  cost of in subhumid states ... 257
  division of, in Utah ... 219
  duty of ... 12, 29, 95, 138, 148, 168, 250
  legislative control of, in Wyoming ... 250
  master, duties of, in Idaho ... 143, 227
  monopoly of, in Utah ... 219
  months used in Montana ... 168
  rights in California, cost per acre of ... 49
  rights in Colorado, defined ... 94
  rights, Colorado, excessive sale of ... 126, 132
  rights, Colorado, valueless ... 120
  right, Idaho, value of ... 143
  storage in California ... 58
    Colorado ... 104, 106, 110, 125
    Idaho ... 138, 155
    Nevada ... 185, 187
    New Mexico ... 195
    Washington ... 245
    Utah, small reservoirs for ... 222
  supply of ... 11, 285
    in Arizona ... 23
    California ... 35
    Colorado ... 93
    Idaho ... 137, 145
    Montana ... 156, 172
    Nevada ... 179
    New Mexico ... 194
    Oregon ... 203, 206
    South Dakota ... 263
    Washington ... 237
    Wyoming ... 249
    the subhumid states ... 259
  supervision, in Montana, necessity of ... 175
  value per acre of, in California ... 42
    per miner's inch of ... 58
    greater than land ... 65
Waterville, Wash., cereals in vicinity of ... 241

Page.

- Water wheels, raising water in Wyoming from the North Platte by 252
  - method of raising water in Washington by 240
- Watt ditch, described 242
- Weber River valley, Utah, the need of storage reservoirs in 228
- Weber river, Utah, discharge above Uinta of 235, 303
- Weeping Child creek, Montana, water supply of 72
- Weirs on Kern river, California 53
- Weiser river, Idaho, discharge of 155, 156, 297
- Weldon Valley ditch, Colorado, described 123
- Wells in Arizona 23, 25
  - Colorado 99, 135
  - Oregon 205
  - Nevada 180
  - New Mexico 195
  - Utah 220
  - Wyoming 250
  - of the subhumid states 259
- Well casing, disadvantage of not using 100
- Wenas or Naches valley, Washington, described 246
- Wenatchee River valley, Washington, irrigation by springs in 242
- West Carson river, Nevada, discharge of 183
- West Gallatin river, Montana, discharge of 167, 299
- Western Irrigation and Land Company, Kansas, described 276
- Wesminster, Cal., flowing wells in vicinity of 66
- West Side irrigating canal, Washington, described 243
- West Side Water Supply Company, South Dakota, described 264
- West Walker river, Nevada, agricultural land in vicinity of 182
- Weston and Campbell ditch, Nevada, described 188
- Wet Mountain valley, Colorado, water supply from 107
- Wheat in Arizona 22
  - California 33, 34, 43
  - Colorado 90
  - Idaho 136
  - Montana 157
  - Nevada 177
  - New Mexico 193
  - Oregon 202
  - Utah 218
  - Washington 236
  - Wyoming 248
- Wheat, decrease acreage in California of 86
  - in Colorado, importance of 98
- White, C. A., Geologic Structure of the Great Plains 98
- White creek, California, discharge of 58
- White river, Colorado, valley of 127
  - Nevada, ditches from 188
- White Salmon river, Washington, Cameron ditch from 243

Page.

- Wild Horse creek, Oregon, water supply of 216
- Willamette river, Oregon, discharge of 237
- Willamette valley, Oregon, irrigation in 202, 203
- Williston, N. Dak., irrigation in vicinity of 260
- Willow creek, Montana, ditches from 168
- Willow Creek valley, Oregon, supply of water in 213
- Willowdale ditch, Colorado, described 104
- Windmills in California, used in pumping wells 68, 78
- Wind River range, Wyoming, streams from 253
- Winnemucca lake, Nevada, described 182
- Winter Creek canal, Nebraska, described 268
- Woodland Ditch Company, California, described 88
- Wood, use of pipes of 19
- Wood river, Idaho, discharge at Hailey of 151, 152
- Wray and Chief Creek ditches, Colorado, described 133
- Wright law, review of 38
- Wyoming—counties of:
  - Albany 251
  - Carbon 251, 252
  - Converse 252
  - Crook 252
  - Fremont 253
  - Johnson 253, 254
  - Laramie 254
  - Natrona 254, 255
  - Sheridan 255
  - Uinta 255, 256
  - Weston 256
- Wyoming Development Company, Wyoming, described 254

Y.

- X Y ditch, Colorado, described 126
- Yakima Irrigation and Improvement Company canal, Washington, described 247
- Yakima river, Washington, lakes in valley of 242, 246, 304
- Yampa river, Colorado, drainage basin of 129
- Yellowstone river, Montana, irrigation in the valley of the 164
- Yellowstone and Canyon Creek canal, Montana, described 176
- Yellowstone river, discharge at Horr, Mont., of 173
- Yreka, Cal., flowing wells in vicinity of 81
- Yuma valley, Colorado, wells of 132

Z.

- Zanja Madra ditch, California, described 59
- Zavalla county, Tex., water taken from Leona river 281
- Zillah, Wash., Sunnyside canal at, described 247

○